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AERODYNAMIC CHARACTERISTICS OF A LARGE-SCALE MODEL
WITH A SWEEP WING AND AUGMENTED JET FLAP

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AERODYNAMIC CHARACTERISTICS OF A LARGE-SCALE MODEL
WITH A SWEPT WING AND AUGMENTED JET FLAP

BY

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SUMMARY

This report presents data of tests of a large-scale swept augmentor wing model in the 40- by 80-foot wind tunnel. The data includes longitudinal characteristics with and without a horizontal tail as well as results of preliminary investigation of lateral-directional characteristics. The augmentor flap deflection was varied from 0° to 70.6° at isentropic Jet Thrust coefficients of 0 to 1.47. The tests were made at a Reynolds number from 2.43×10^6 to 4.1×10^6 .

INTRODUCTION

The augmentor wing concept is being studied as one means for attaining STOL performance in turbofan powered aircraft. Initial tests on an unswept wing model in the 40- by 80-foot wind tunnel were reported on in reference 1. Another series of tests with the same model but with a modified augmentor configuration and with the model equipped with wing mounted engines are reported in reference 2.

The tests reported herein initiate the investigation of the application of the augmentor to a swept wing. The wing configuration of the model used was swept $27\text{-}1/2^\circ$ at the quarter chord line but was similar to the unswept wing in aspect ratio, taper ratio, and spanwise extent of the augmentor. The tests were made out of ground effect for flap settings from 0° to 70° with and without a horizontal tail. A major portion of the tests were made at zero sideslip but a small amount of lateral stability and control data were obtained.

The tests were made in cooperation with the Defense Research Board of Canada and the De Havilland Aircraft of Canada Limited.

NOTATION

A	thrust augmentation ratio of jet augmentor, J_A/J_I
b	wing span, m(ft)
BLC	boundary layer control
c	chord, m(ft)
\bar{c}	mean aerodynamic chord, m(ft)
C_D	drag coefficient, $\frac{\text{drag}}{qS}$
C_{D_m}	total momentum drag coefficient due to gas generator and compressor gas flow
$C_{J_{AI}}$	isentropic augmentor jet force coefficient, (see text) $\frac{\text{isentropic force}}{qS}$
C_{J_I}	total isentropic jet thrust coefficient, $C_{J_{AI}} + C_{\mu_{aI}} + C_{\mu_{FI}}$
C_f, C_R	rolling moment coefficient, $\frac{\text{rolling moment}}{qSb}$
C_L	lift coefficient, $\frac{\text{lift}}{qS}$
C_m	pitching moment coefficient, $\frac{\text{pitching moment}}{qS\bar{c}}$
C_n	yawing moment coefficient, $\frac{\text{yawing moment}}{qSb}$
$C_{T_{JP}}$	jet pipe thrust coefficient, $\frac{\text{thrust}}{qS}$
C_Y	side force coefficient, $\frac{\text{side force}}{qS}$
$C_{\mu_{aI}}$	isentropic aileron BLC coefficient, $\frac{\text{isentropic BLC force}}{qS}$
$C_{\mu_{FI}}$	isentropic fuselage BLC coefficient, $\frac{\text{isentropic BLC force}}{qS}$
d	distance between trailing edge of flap and shroud, m(ft) (see fig. 2(e))
i_t	horizontal tail incidence, positive with trailing edge down, deg

J_A	augmentor jet force at $q = 0$, n/m^2 (psf)
J_I	isentropic jet force at $q = 0$, n/m^2 (psf)
q	free-stream dynamic pressure, n/m^2 (psf)
S	wing area, sq m(sq ft)
t	airfoil thickness, m(ft)
x	chordwise station, m(ft)
y	airfoil ordinate, m(ft)
Z_{JP}	distance between moment center and line of action of Jet-pipe residual thrust, m(ft)
α, AL	model angle of attack, deg
β	angle of sideslip of plane of symmetry, deg
δ_a	aileron deflection ($\delta_a = 45/60$ means left aileron at 45° , right aileron at 60°) positive with trailing edge down, deg
δ_e	elevator deflection, positive with trailing edge down, deg
δ_f	augmentor flap deflection, positive with trailing edge down, deg (see figure 2(e))
δ_{ID}	augmentor intake door deflection, positive with leading edge down, deg (see figure 2(e))
δ_{JP}	deflection of jet pipes relative to fuselage datum plane, deg
δ_s	slat deflection, positive with leading edge down, deg (see figure 2(c))
δ_{SP}	spoiler deflection, trailing edge up, deg (see figure 2(k))
Δ_d	augmentor throttling, reduction in distance between trailing edge of flap and shroud in percent of d.
θ	augmentor jet angle relative to wing chord plane, deg

SUBSCRIPTS

a	aileron
A	augmentor
f	flap
F	fuselage
JP	jet-pipe
I	isentropic
L	left
R	right
s	slat
u	uncorrected
V	Viper
w	wing

MODEL AND APPARATUS

Basic Model

The model is shown installed in the wind tunnel in figure 1. Geometric details are shown in figure 2 and reference dimension are listed in table I - III. The air for the augmentor and BLC systems on the model was supplied by a pump consisting of a J-85 coupled pneumatically to two turbocompressors that were modified Viper engines. The turbocompressors supplied air for the augmentor and ailerons.

The wing and horizontal tail planform geometry are presented in figure 2(b) and 2(d). The wing leading edge slat geometry is presented in figure 2(c). To increase the maximum lift coefficient the right tip slat was modified during the test. The modification consisted of reducing the slat gap to .019c and increasing the overlap to .006c for the outboard 24.5% semispan.

Augmentor Flap

The geometry of the augmentor flap cross section is shown in figure 2(e). The augmentor is an ejector system consisting of a trailing edge primary nozzle (figure 2(f)) through which the compressed air is delivered, (lower) flap, (upper) shroud, and intake door. The secondary air is entrained from the wing upper surface, the slot between the intake door and shroud, and the tertiary gap between the wing lower surface and flap. The mixed jet is ejected downward between the flap and the shroud. The angle of the intake door was optimized for each flap deflection. During a series of tests the tertiary gap was sealed to determine its effect on augmentor performance (see figure 2(e)).

The ducting for the primary air and aileron BLC is shown in figures 2(g) and 2(h). Figure 2(h) shows the variation of duct diameter with wing span which was designed to maintain in duct mach number of .36.

Fuselage BLC

The fuselage BLC installation is shown in figure 2(j). It was located just aft of the wing leading edge in the part of the wing spanning the fuselage for the purpose of preventing airflow separation at the wing fuselage juncture by energizing the fuselage boundary layer. The BLC air was provided by J-85 compressor bleed air.

Aileron BLC

The geometry of the aileron BLC system is shown in figure 2(k). The system was fed through an extension of the augmentor primary air duct. Aileron blowing was therefore coupled with the augmentor output. Airflow to the aileron was approximately 5% of total turbo-compressor output.

Lateral Control System

The model was equipped with several methods for lateral control:

Ailerons. - Lift requirements for landing and takeoff resulted in symmetrical drooping of the BLC aileron by as much as 45°. Lateral control was obtained by differentially deflecting the ailerons.

Spoilers. - Upper wing panel type spoilers were installed on the left wing for lateral control as shown in figure 2(k). The spoilers were 11.2% of wing chord, located ahead of the aileron.

Augmentor Throttling. - A flap plate was installed on the lower portion of the flap of the outer 50% of the port wing augmentor as shown in figure 2(e).

This simulates a deflected aft portion of the flap to reduce the augmentor exit area and affect a local throttling of the augmentor eflux to create a rolling moment.

TEST

Test procedure consisted primarily of varying angle of attack at constant C_{J_I} . The angle of attack range was -8 to 30° . Sideslip range was from -6 to 11° . Augmentor flap deflection was varied from 0° (the shroud was left in its normal position) to 70.6° .

The position of the augmentor intake door was optimized at each flap deflection. The ailerons were normally deflected 30° . For each flap deflection tests were made at several C_{J_I} 's.

DATA REDUCTION

For all force and moment data, the effects of compressor residual jet thrust, and the intake momentum drag of the fuselage mounted J85 and Viper engines, have been subtracted from the measured values. Forces and moments are referred to the stability axes. The corrections made for thrust and ram drag are as follows:

$$C_L = C_{L_u} - C_{T_{JP}} \sin (\alpha_u - \delta_{JP})$$

$$C_{D_{net}} = C_{D_u} + C_{T_{JP}} \cos (\alpha_u - \delta_{JP}) - C_{D_{mJ85}} - C_{D_{MV}}$$

$$C_{m_{net}} = C_{m_u} - C_{T_{JP}} \frac{Z_{JP}}{\bar{c}}$$

Wind tunnel boundary corrections were based upon the "aerodynamic C_L ", computed as follows:

$$\begin{aligned}
 C_{L_{AERO}} &= C_{L_U} - C_{J_A} (A_{net}) \sin (\theta + \alpha_u) && \text{(Augmentor)} \\
 -C_{\mu_{aL}} \sin (\delta_{aL} + \alpha_u) \frac{S_a}{S} &&& \text{(Aileron BLC, left)} \\
 -C_{\mu_{aR}} \sin (\delta_{aR} + \alpha_u) \frac{S_a}{S} &&& \text{(Aileron BLC, right)} \\
 -C_{\mu_F} \sin \alpha_u \left(\frac{S_F}{S} \right) &&& \text{(Fuselage BLC)}
 \end{aligned}$$

Thus the following boundary corrections were made:

$$\begin{aligned}
 \alpha &= \alpha_u + .458 C_{L_{AERO}} \\
 C_D &= C_{D_u} + .00799 C_{L_{AERO}}^2 \\
 C_m &= C_{m_u} + .023 C_{L_{AERO}} && \text{(tail on only)}
 \end{aligned}$$

The moment center used for data computation was located longitudinally at $0.25 \bar{c}$ and vertically $0.20 \bar{c}$ below the wing chord datum.

The $C_{J_{AI}}$ is the force coefficient computed on the basis of the measured mass flow and total pressure in the duct prior to discharge (see figure 2(g) for measuring station). Based on previous tests of a similar nozzle (ref. 1 and 2), the nozzles losses are expected to be 5 to 10 percent, and therefore the nozzle force coefficient would be 5 to 10 percent lower than $C_{J_{AI}}$.

PRESENTATION OF DATA

The longitudinal aerodynamic characteristics of the model are presented in figures 3 to 26. Data with and without the horizontal tail are presented in these figures. An index to the figures is given in Table IV.

The lateral-directional characteristics of the model are presented in figures 27 to 39. The data includes the effect of spoilers, augmentor throttling, and differential aileron deflection. An index to these figures is shown in Table V.

REFERENCES

1. Koenig, D. G.; Corsiglia, V. R.; Morelli, J. P.: Aerodynamic Characteristics of a Large Scale Model with an Unswept Wing and Augmented Jet Flap. NASA TN D-4610, 1968.
2. Cook, A. M.; Aiken, T. N.: Low Speed Aerodynamic Characteristics of a Large Scale STOL Transport Model With an Augmented Jet Flap. NASA TM X-62017, 1971.

TABLE I. - WING REFERENCE DIMENSION

Wing area, sq m(sq ft)	21.36(230.0)
Aspect ratio	8.0
Span, m(ft)	13.08(42.895)
Taper ratio	0.30
Sweep at 1/4 chord, deg	27.5
Airfoil section	RAE 104
Root chord, m(ft)	2.515(8.25)
Tip chord, m(ft)	0.755(2.475)
Root thickness, percent	12 1/2
Tip thickness, percent	10 1/2
Augmentor span limits, Inner, m(ft) (percent)	1.111(3.645) (12.34)
Augmentor span limits, Outer, m(ft) (percent)	4.575(15.01) (70.0)
Wing area spanned by one augmentor, sq m(sq ft)	6.75(72.62)
Wing area spanned by one aileron, sq m(sq ft)	1.997(21.50)
Wing area spanned by fuselage, sq m(sq ft)	3.88(41.77)
Flap hinge axis, percent chord	68.543
Aileron hinge axis, percent chord	68.0
Incidence, camber, twist	0
Mean aerodynamic chord, m(ft)	1.793(5.880)

NOTE: All chords are measured in streamwise direction.

TABLE II. - TAIL REFERENCE DIMENSION

Horizontal Tail

Gross area, sq m(sq ft)	55.77(60.0)
Aspect ratio	4.5
Span, m(ft)	5.005(16.432)
Taper ratio	0.40
Sweep at 1/4 chord, deg	25
Airfoil section	RAE 104 with modified l.e.
Thickness/Chord ratio, percent	10
Root chord, m(ft)	1.591(5.22)
Tip chord, m(ft)	0.635(2.082)
Elevator hinge axis, percent chord	60
Elevator travel, deg	±30
Tailplane incidence, deg	±12
Tailplane arm, m(ft)	6.804(22.32)
Tailplane volume coefficient	0.990
Mean aerodynamic chord, m(ft)	1.114(3.654)

Vertical Fin

Fin arm, m(ft)	5.361(17.603)
Fin volume coefficient	0.07476

TABLE III. - COORDINATES OF R.A.E. 104 AIRFOIL(t/c max.=.10)

X/C	Y/C 100	X/C	Y/C 100
0	0	0.35	4.9300
0.001	0.3441	0.36	4.9488
0.002	0.4863	0.38	4.9775
0.003	0.5953	0.4	4.9946
0.004	0.6870	0.42	5.0000
0.005	0.7676	0.44	4.9937
0.006	0.8404	0.45	4.9862
0.007	0.9072	0.46	4.9756
0.0075	0.9387	0.48	4.9454
0.008	0.9692	0.5	4.9027
0.009	1.0274	0.52	4.8468
0.01	1.0824	0.54	4.7769
0.012	1.1842	0.55	4.7363
0.0125	1.2083	0.56	4.6917
0.014	1.2776	0.58	4.5802
0.016	1.3642	0.6	4.4650
0.018	1.4452	0.62	4.3113
0.02	1.5215	0.64	4.1370
0.025	1.6960	0.65	4.0438
0.03	1.8522	0.66	3.9473
0.035	1.9945	0.68	3.7452
0.04	2.1256	0.7	3.5331
0.05	2.3617	0.72	3.3128
0.06	2.5709	0.74	3.0861
0.07	2.7592	0.75	2.9708
0.075	2.8468	0.76	2.8545
0.08	2.9307	0.78	2.6103
0.09	3.0881	0.8	2.3819
0.1	3.2336	0.82	2.1437
0.12	3.4945	0.84	1.9055
0.14	3.7222	0.85	1.7864
0.15	3.8254	0.86	1.6673
0.16	3.9224	0.88	1.4202
0.18	4.0992	0.9	1.1910
0.2	4.2556	0.92	0.9528
0.22	4.3936	0.925	0.8932
0.24	4.5149	0.94	0.7146
0.25	4.5697	0.95	0.5955
0.26	4.6208	0.96	0.4764
0.28	4.7124	0.975	0.2977
0.3	4.7905	0.98	0.2382
0.32	4.8556	0.9875	0.1489
0.34	4.9082	1.0	0

TABLE IV. - INDEX OF DATA FIGURES; LONGITUDINAL

FIGURE	EFFECT	β	δ_f	δ_a	δ_s	SLAT MOD.	HORIZ. TAIL	FUS. BLC	C_{J_I}		
3a	Tertiary seal ↓	0	41.1	30	60	ON	OFF	OFF	1.47		
b			↓	↓	↓	↓	↓	↓	.77		
c			↓	↓	↓	↓	↓	↓	.36		
d			↓	↓	↓	↓	↓	↓	↓		
4a			70.6	↓	↓	↓	↓	↓	1.10		
b	↓		↓	↓	↓	↓	↓	↓	↓		
5	δ_{ID}		↓	↓	45	↓	OFF	↓	↓	.77	
6	δ_a ↓		31.8	↓	↓	↓	ON	↓	↓	.18, .77	
7			41.1	↓	↓	↓	↓	↓	↓	.77	
8a			70.6	↓	↓	↓	OFF	↓	↓	.77	
b			↓	↓	↓	↓	↓	↓	↓	.77, 1.10	
c			↓	↓	↓	50	↓	↓	↓	1.10	
9a			↓	↓	↓	60	↓	ON	↓	.77	
b			↓	↓	↓	↓	ON	↓	↓	↓	
10a			FUS. BLC	↓	↓	15	↓	OFF	OFF	~	↓
b			↓	↓	↓	45	↓	↓	↓	↓	1.10
c			↓	↓	↓	30	50	↓	↓	↓	1.10
d	↓		↓	↓	↓	60	ON	ON	↓	.77, 1.47	
11a	↓		↓	↓	↓	50, 60	OFF	OFF	OFF	1.10	
b	↓		↓	↓	↓	60	ON	↓	↓	↓	
12a	δ_s		↓	↓	↓	↓	OFF	ON	↓	0	
b	δ_e ↓		↓	↓	↓	↓	↓	↓	↓	.77	
13a			↓	↓	60	↓	↓	↓	↓	1.10	
b			↓	↓	↓	↓	ON	↓	↓	.77	
c			↓	↓	↓	↓	↓	↓	↓	1.10	
d			↓	↓	↓	↓	ON, OFF	↓	↓	.77, 1.10	
14	↓		41.1	↓	↓	↓	ON	↓	↓	.77	
15	i_t		↓	↓	↓	↓	↓	↓	↓	1.10	
16	C_{J_I} ↓		70.6	↓	↓	↓	OFF	OFF	↓	.77	
17			0	4	50	↓	↓	↓	↓	↓	
18			31.8	30	60	ON	↓	↓	↓	↓	
19a			41.1	↓	↓	↓	OFF	↓	↓	↓	
b			↓	↓	↓	↓	ON	↓	↓	↓	
20			51.1	↓	↓	↓	OFF	↓	↓	↓	
21			61.2	↓	↓	↓	↓	↓	↓	↓	
22a			70.6	↓	↓	↓	↓	↓	↓	↓	
b			↓	↓	↓	↓	ON	↓	↓	↓	
23			31.8	↓	↓	↓	↓	ON	↓	↓	
24			41.1	↓	↓	↓	↓	↓	↓	↓	
25			51.1	↓	↓	↓	↓	↓	↓	↓	
26a			70.6	↓	↓	↓	OFF	↓	↓	↓	
b			↓	↓	↓	↓	↓	↓	↓	↓	
c			↓	↓	↓	↓	ON	↓	↓	↓	

TABLE V. - INDEX OF DATA FIGURES: LATERAL-DIRECTIONAL.

FIGURE	EFFECT	β	δ_f	δ_a	δ_s	SLAT MOD.	HORIZ. TAIL	FUS. BLC	C_{J_I}
27a	δa	0	41.1	45/15	60	ON	ON	OFF	.77
b	↓	↓	↓	~ / 30	↓	↓	↓	↓	↓
28a			70.6	45/15					
b			↓	~ / 30					↓
c			↓	↓					.77, 1.10
29	$\delta a, \alpha$		↓	45/15					.77
30	augmentor		41.1	30					.77, 1.10
31a	throttling		↓	↓					↓
b	↓		↓	~ / 30					.77
32			70.6	30					.77, 1.10
33a			↓	~ / 30					.77
b			↓	30					↓
34a	δSP		↓	↓					.77
b	↓		↓	↓					.77, 1.10
c			↓	~ / 30					.77
35a			↓	30					.77
b	↓		↓	↓					1.10
36a	$\beta, \alpha = 0$		↓	↓					~
b	$\beta, \alpha = 12$		↓	↓					↓
c	β, α		↓	↓					.77
d	↓		↓	↓					↓
e	β	-6, +6	↓	↓					↓
37a	$\beta, \alpha = 4$	↓	41.1	↓					~
b	$\beta, \alpha = 12$	↓	↓	↓					↓
c	β, α	↓	↓	↓					.77
38	i_t	-6, 0, +6	↓	↓			↓		↓
39	TAIL	0	↓	↓	↓	↓	ON, OFF	↓	↓

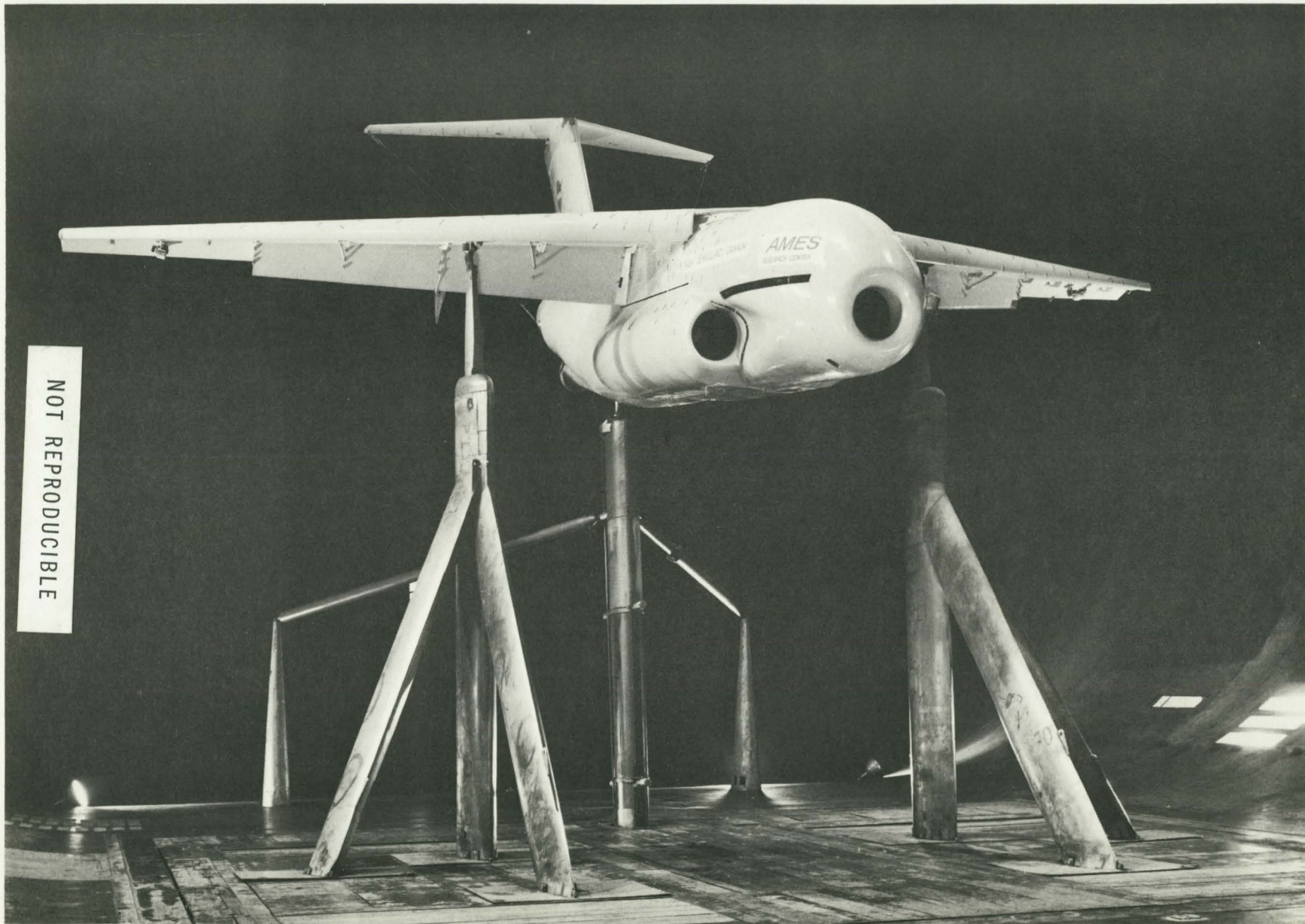
NOT REPRODUCIBLE



(a) Top View

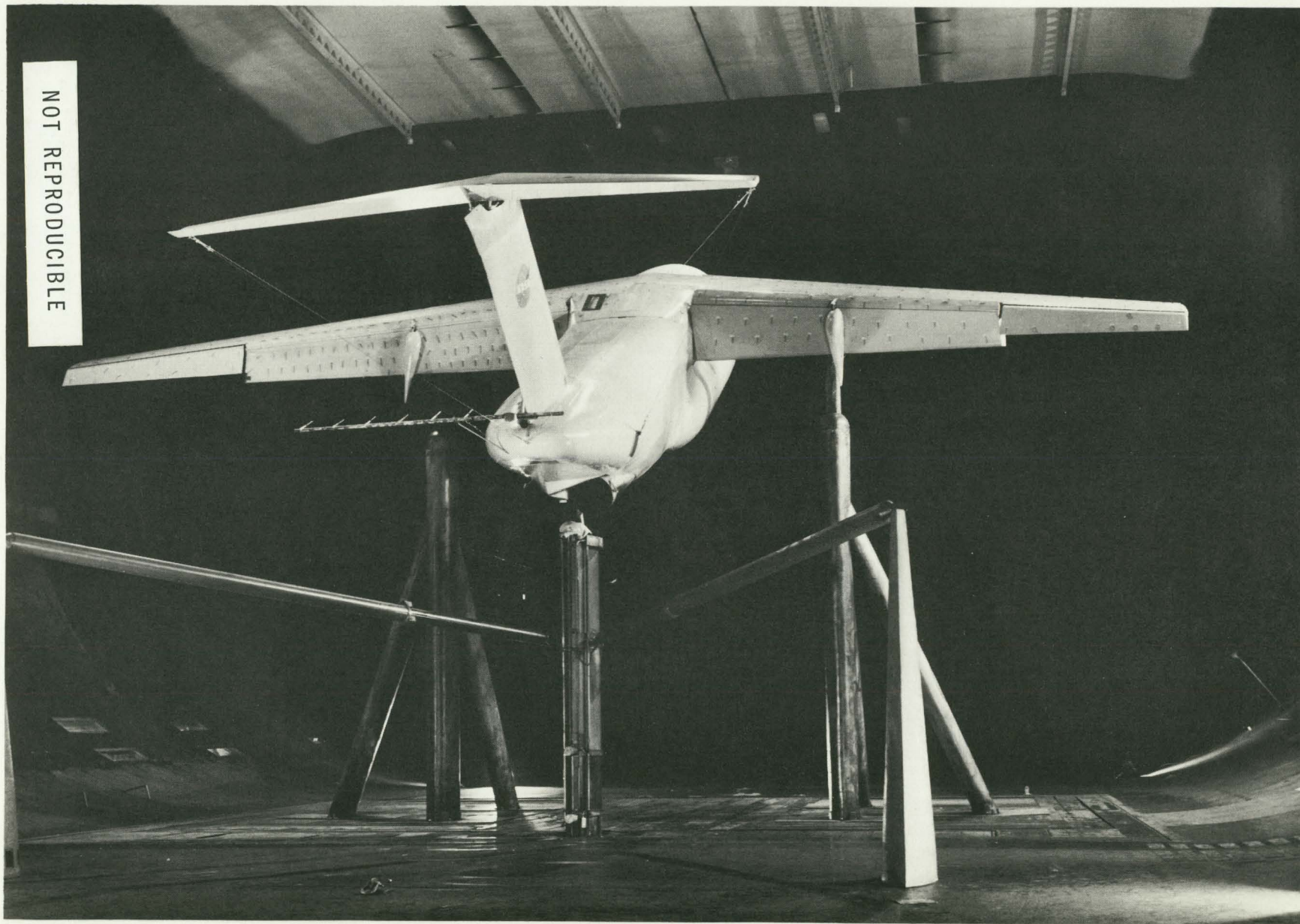
Figure 1.- Photographs of the model installed in the Ames 40- by 80-foot wind tunnel.

NOT REPRODUCIBLE

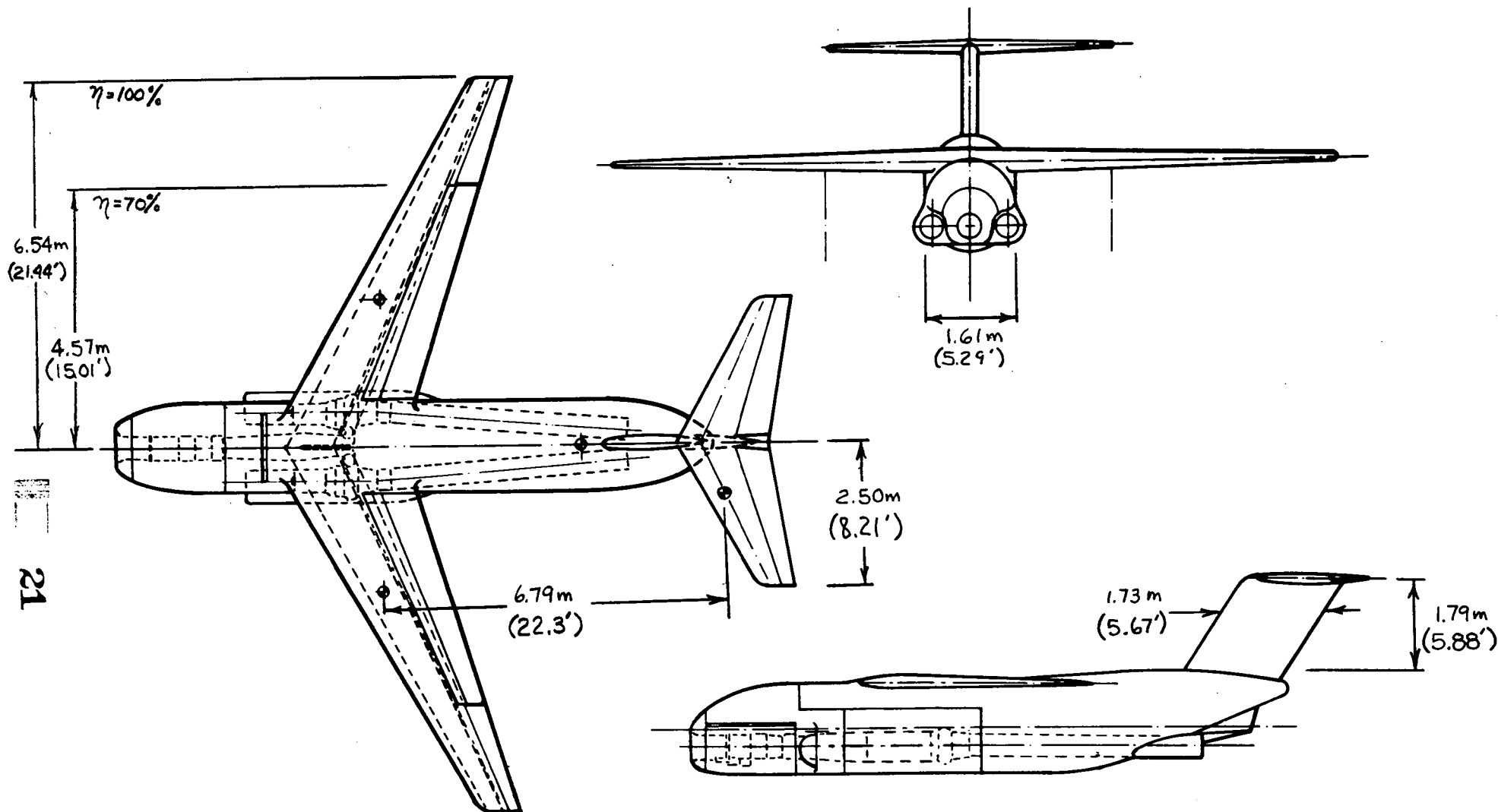


(b) Three-quarter front view
Figure 1.- Continued.

NOT REPRODUCIBLE

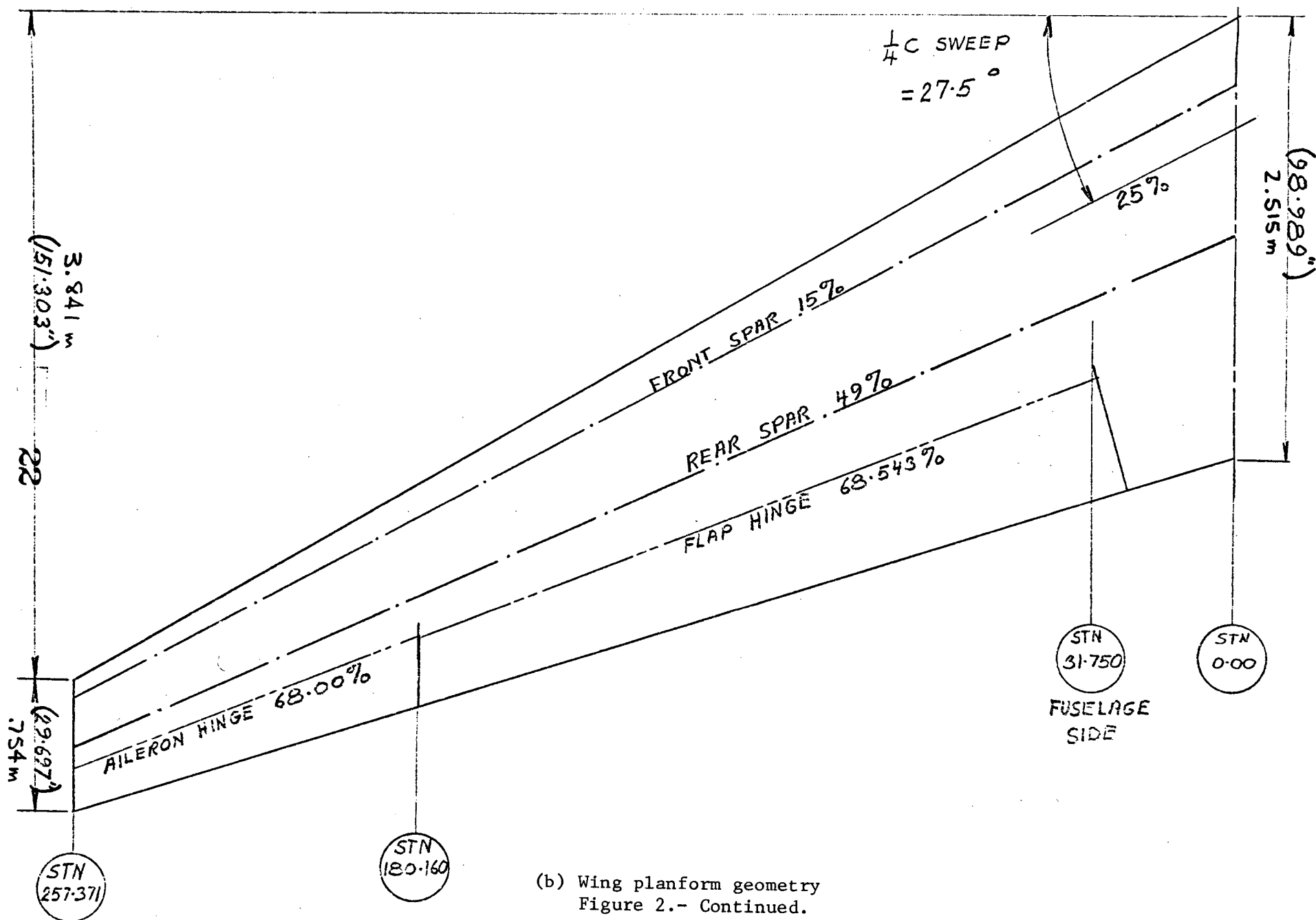


(c) Three-quarter rear view
Figure 1.- Concluded.

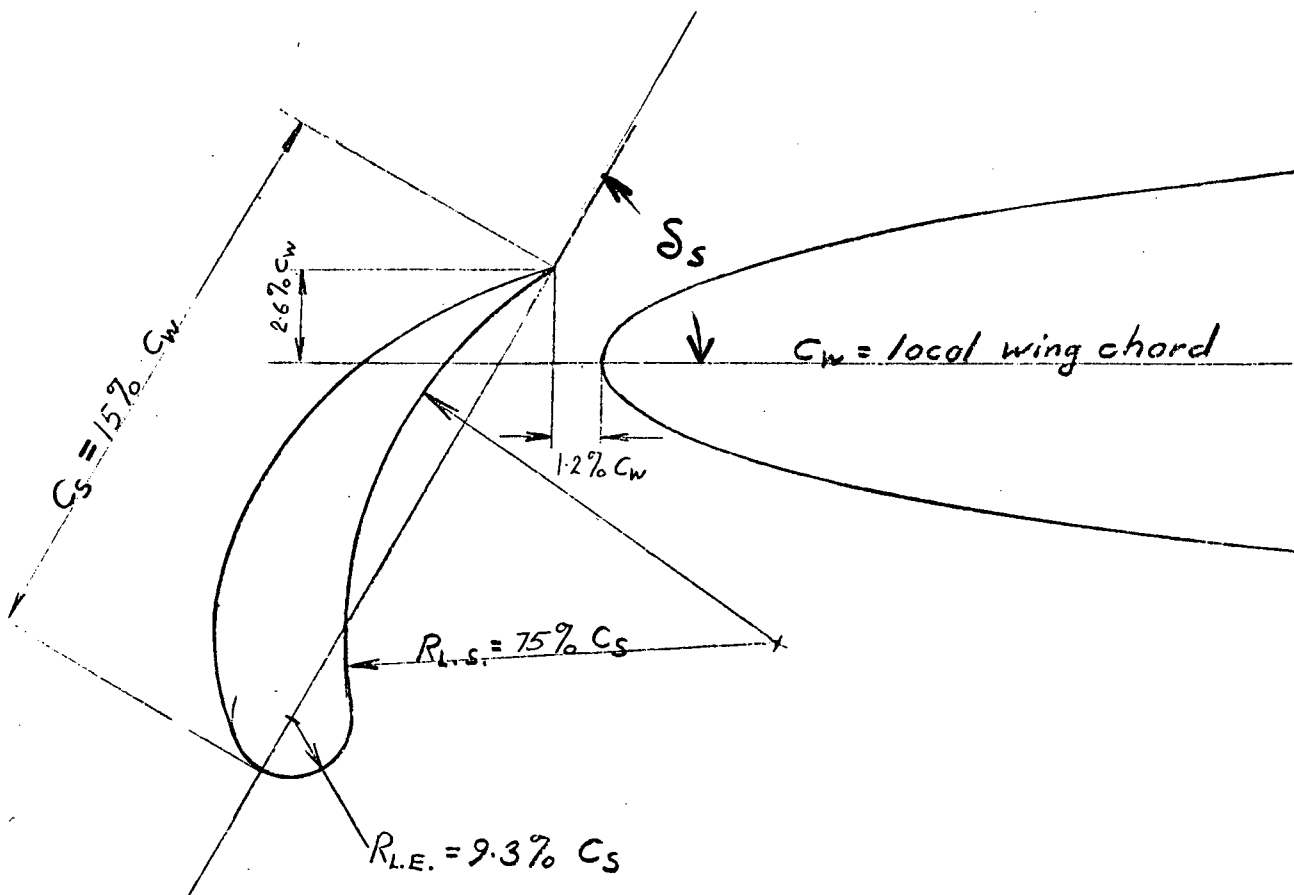


(a) General arrangement

Figure 2.- Geometric details of the model.

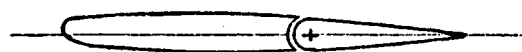
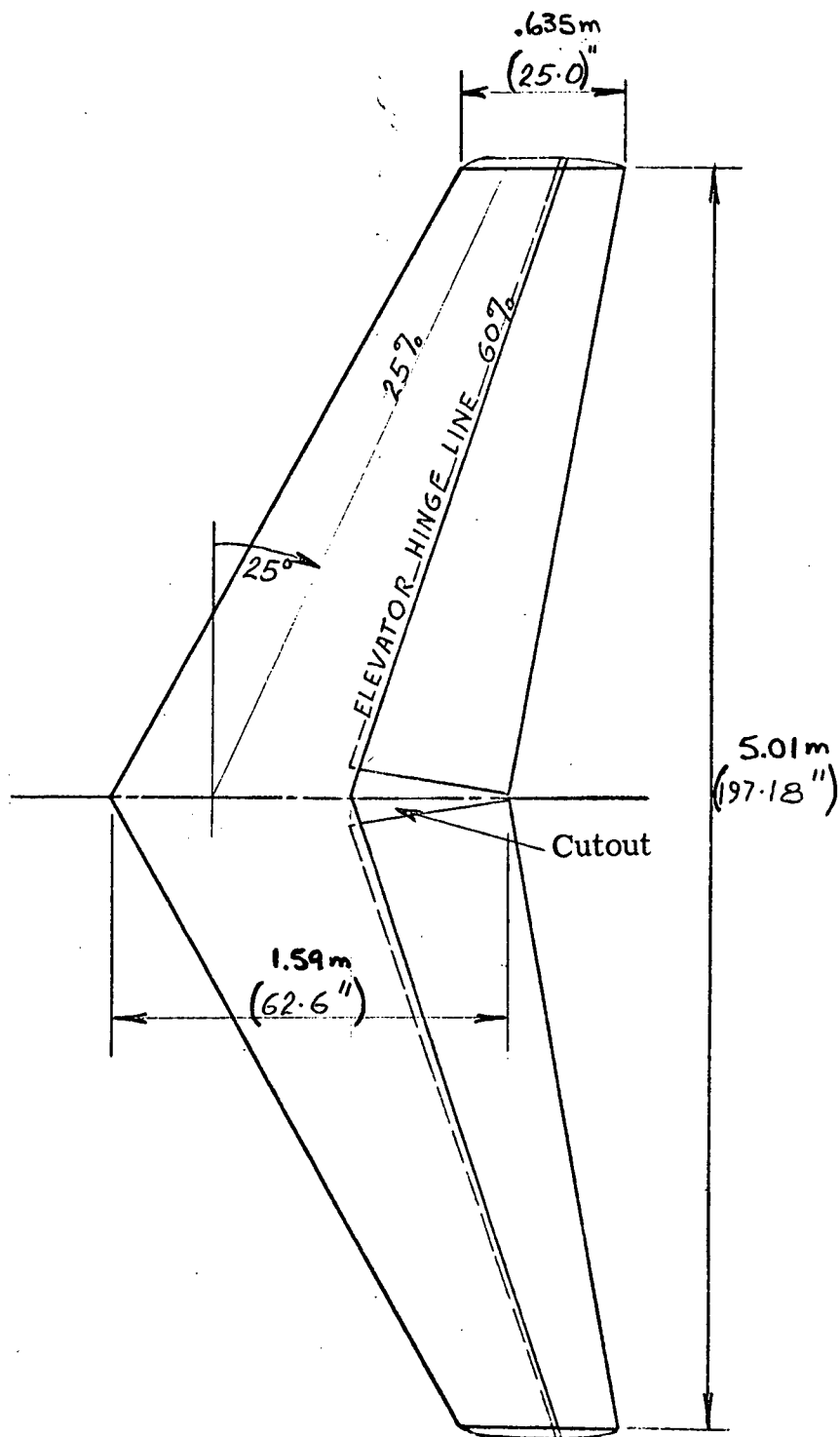


(b) Wing planform geometry
Figure 2.- Continued.



SLAT CO-ORDINATES	
x/c _s	y/c _s
	Upper
0.025	0.0667
0.05	0.1000
0.10	0.1520
0.15	0.1843
0.20	0.2088
0.25	0.2255
0.30	0.2375
0.40	0.2500
0.50	0.2476
0.60	0.2265
0.70	0.1941
0.80	0.1431
0.90	0.0794
1.00	0.0000
L/E RADIUS = 9.314% c _s	

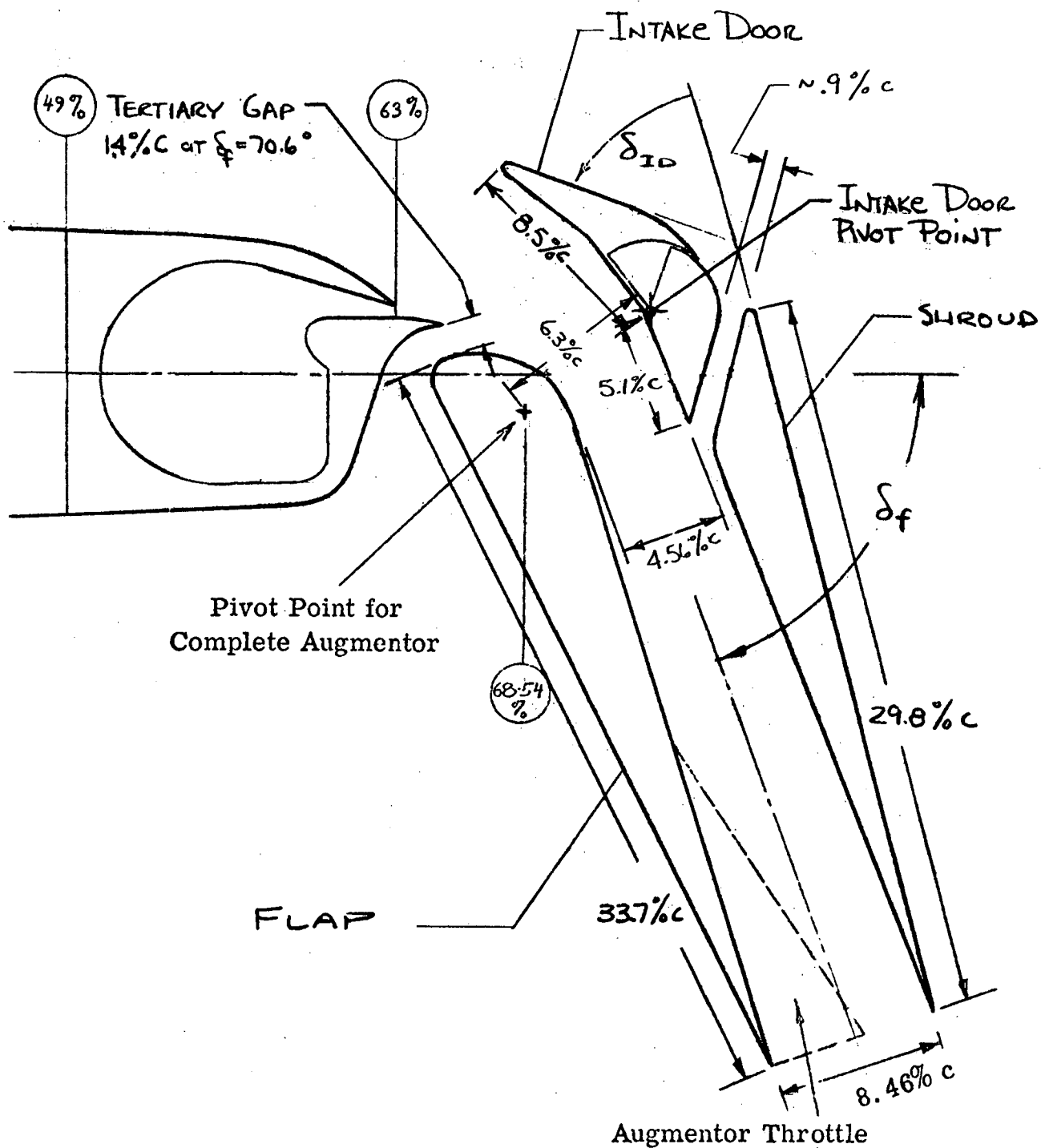
(c) Leading edge slat geometry
Figure 2.- Continued.



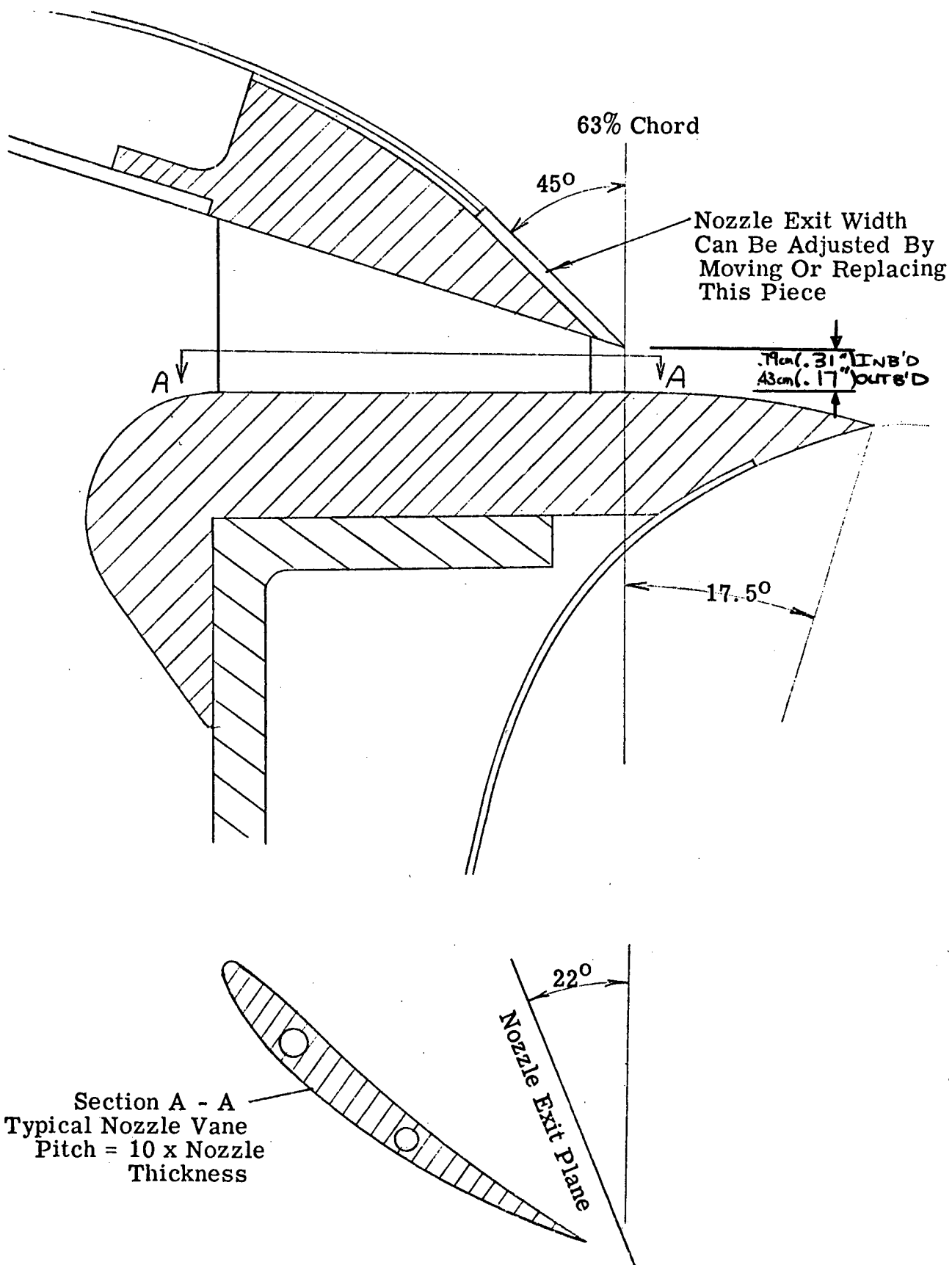
RAE 104 10% $\frac{t}{c}$
(with modified L.E.)

Elevator Travel = $\pm 30^\circ$
Tailplane Incidence = $\pm 12^\circ$

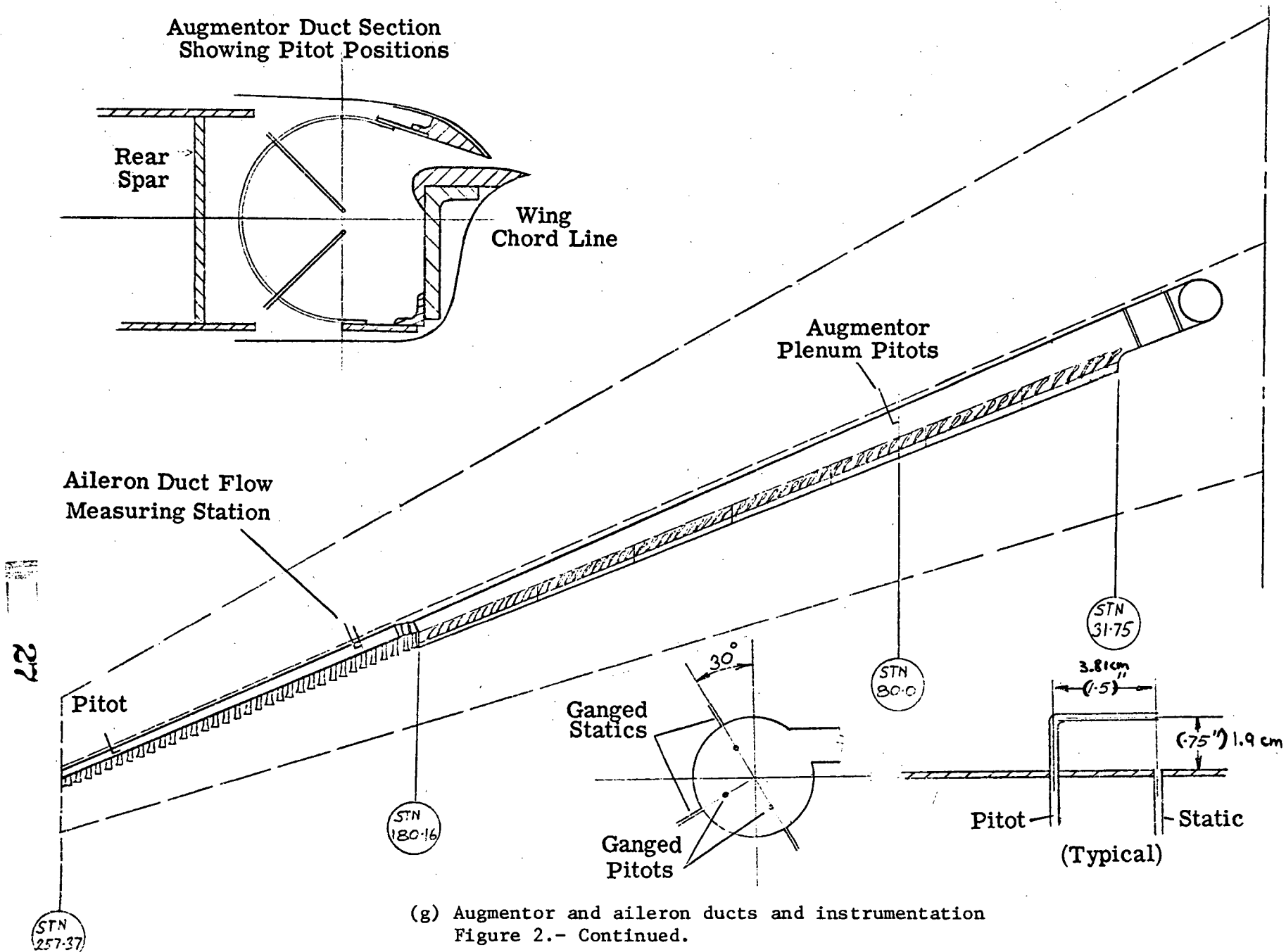
(d) Horizontal tail geometry
Figure 2.- Continued.



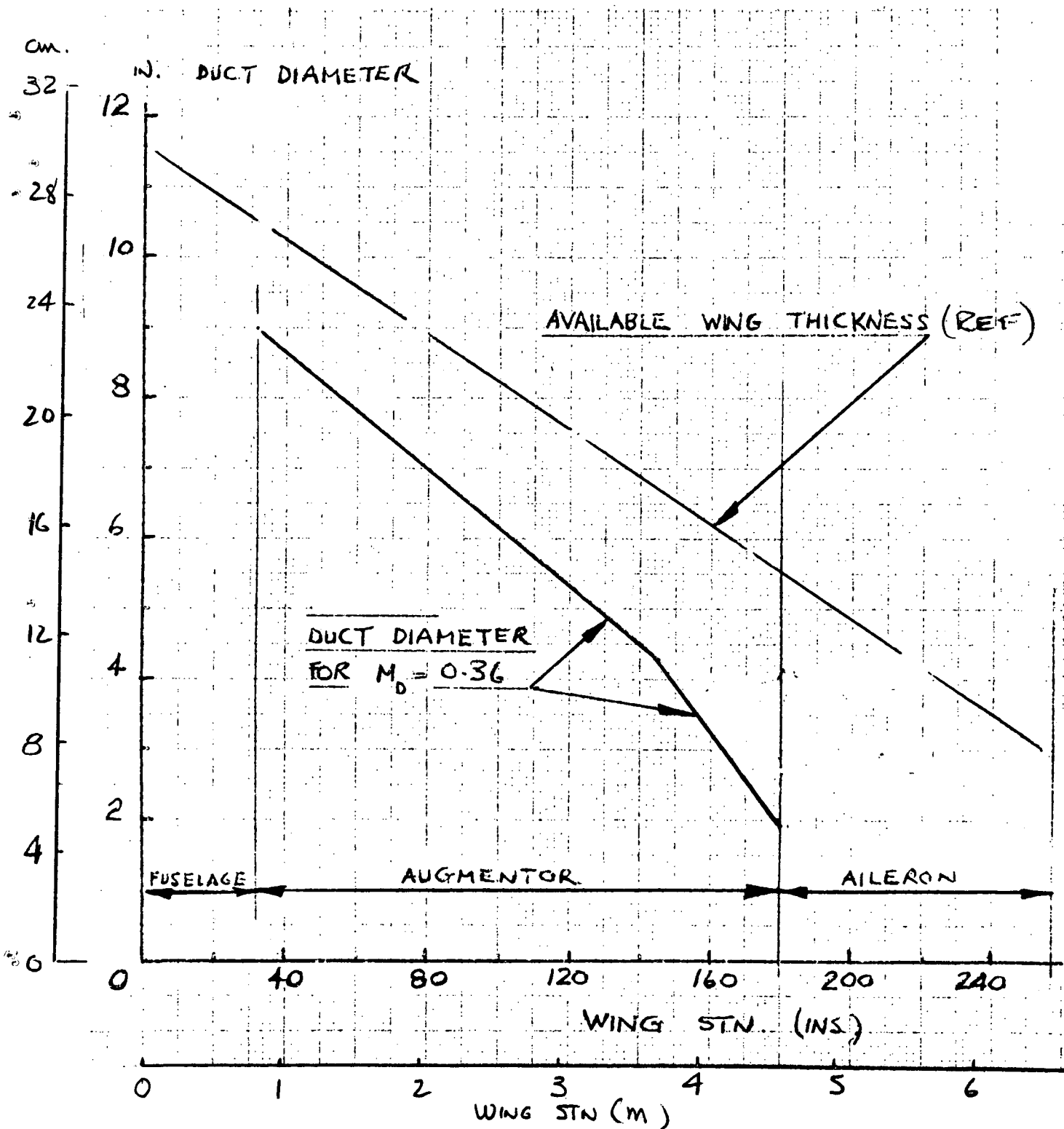
(e) Streamwise section of augmentor flap
Figure 2.- Continued.



(f) Augmentor nozzle cross section
Figure 2.- Continued.



(g) Augmentor and aileron ducts and instrumentation
Figure 2.- Continued.



(h) Augmentor duct size to produce streamwise flow at nozzle exit

Figure 2.- Continued.

J-85 gas generator (compressor bleed for fuselage BLC)

Airflow

Model C

Viper 8 load compressors

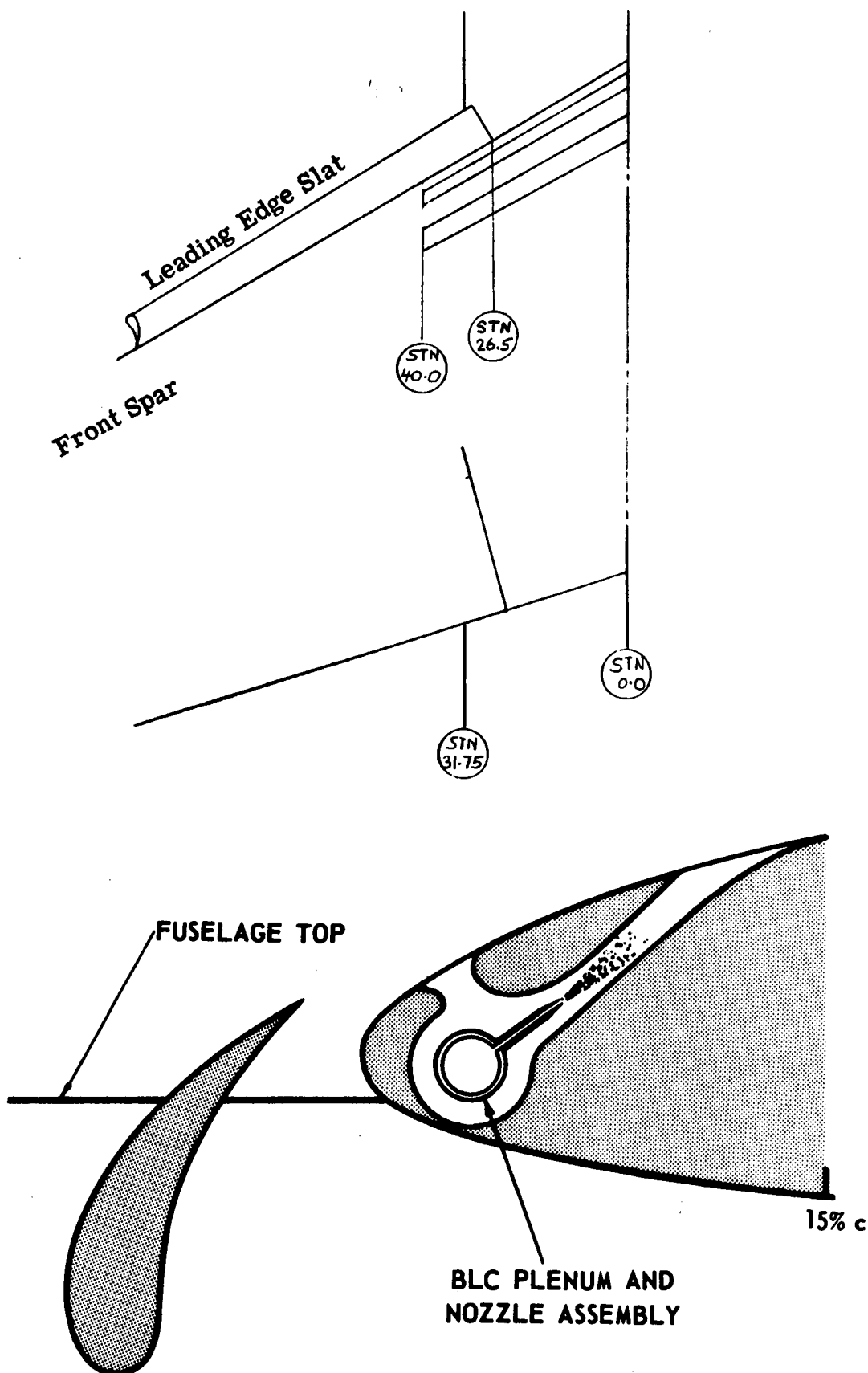
Hot gas exhaust

Air supplies to wing jet augmentors and aileron BLC

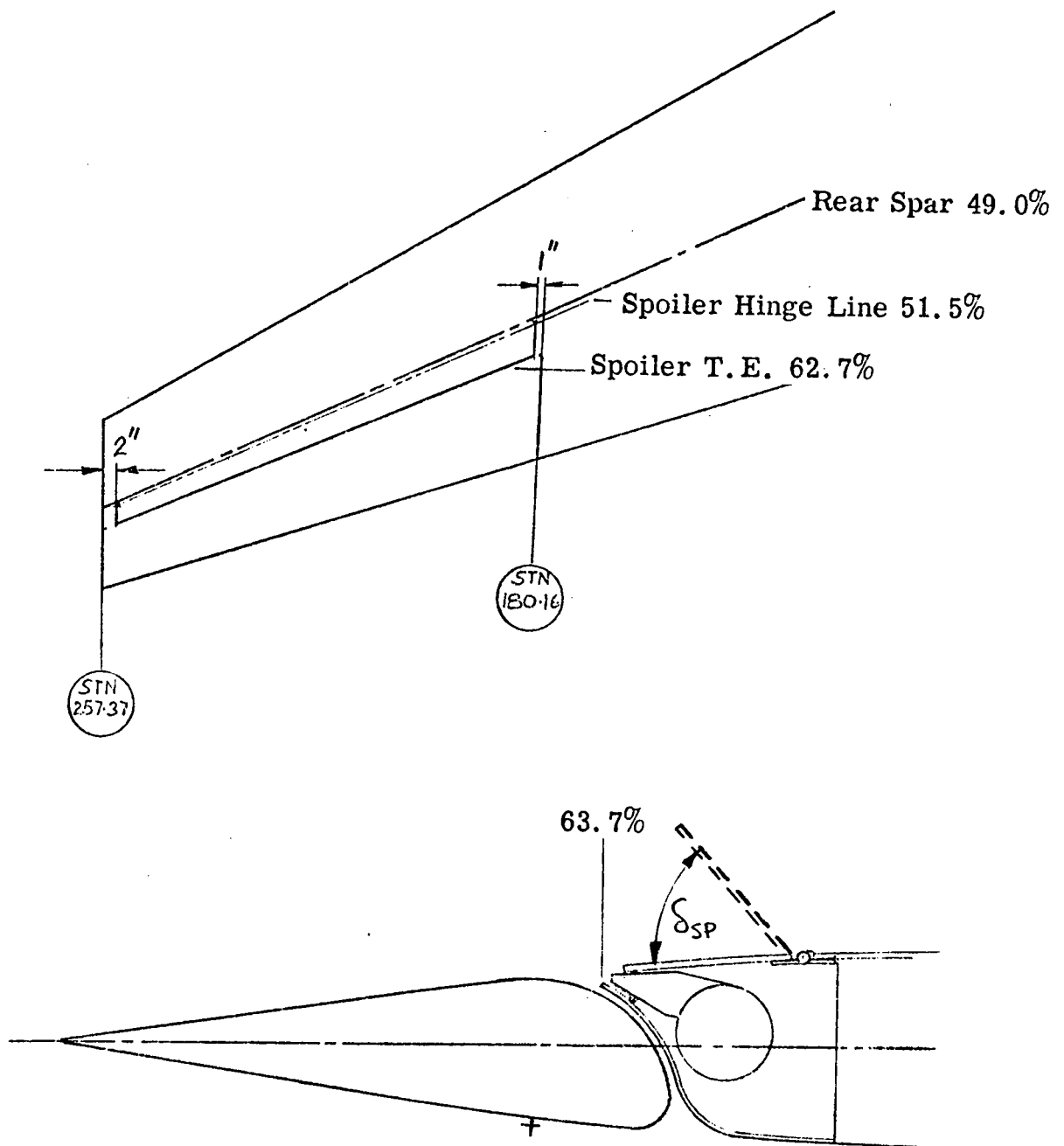
Model C

(i) Augmentor air compressor system.

Figure 2.- Continued.



(j) Fuselage BLC geometry.
Figure 2.- Continued.



(k) Aileron blowing and lift spoiler geometry
Figure 2.- Concluded.

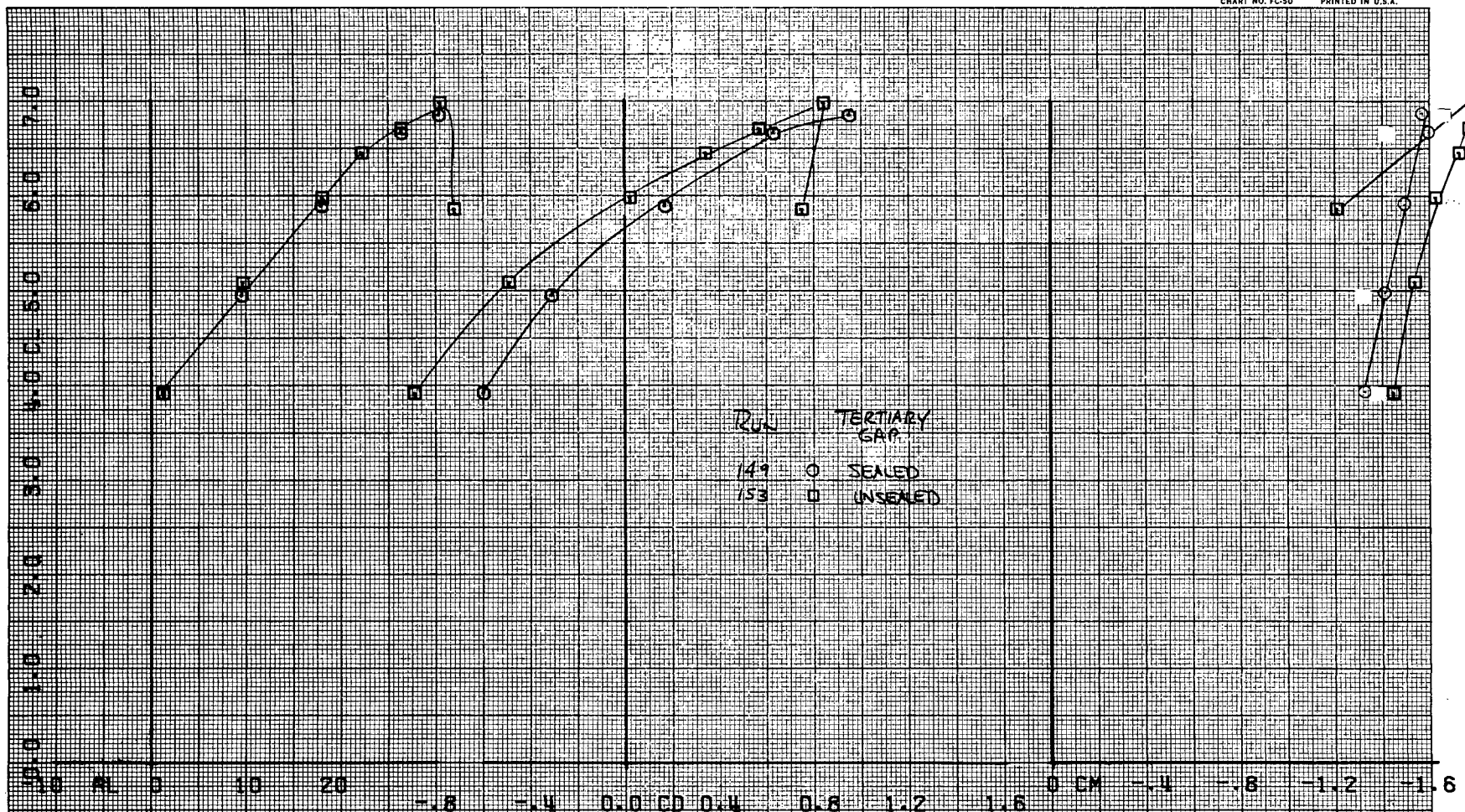
FIRST RUN IS 149.

COMPLOT™

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DIVISION OF HOUSTON INSTRUMENTS
BELLAIRE, TEXAS

CHART NO. FC-50 PRINTED IN U.S.A.



(a) $C_{J_I} = 1.47$

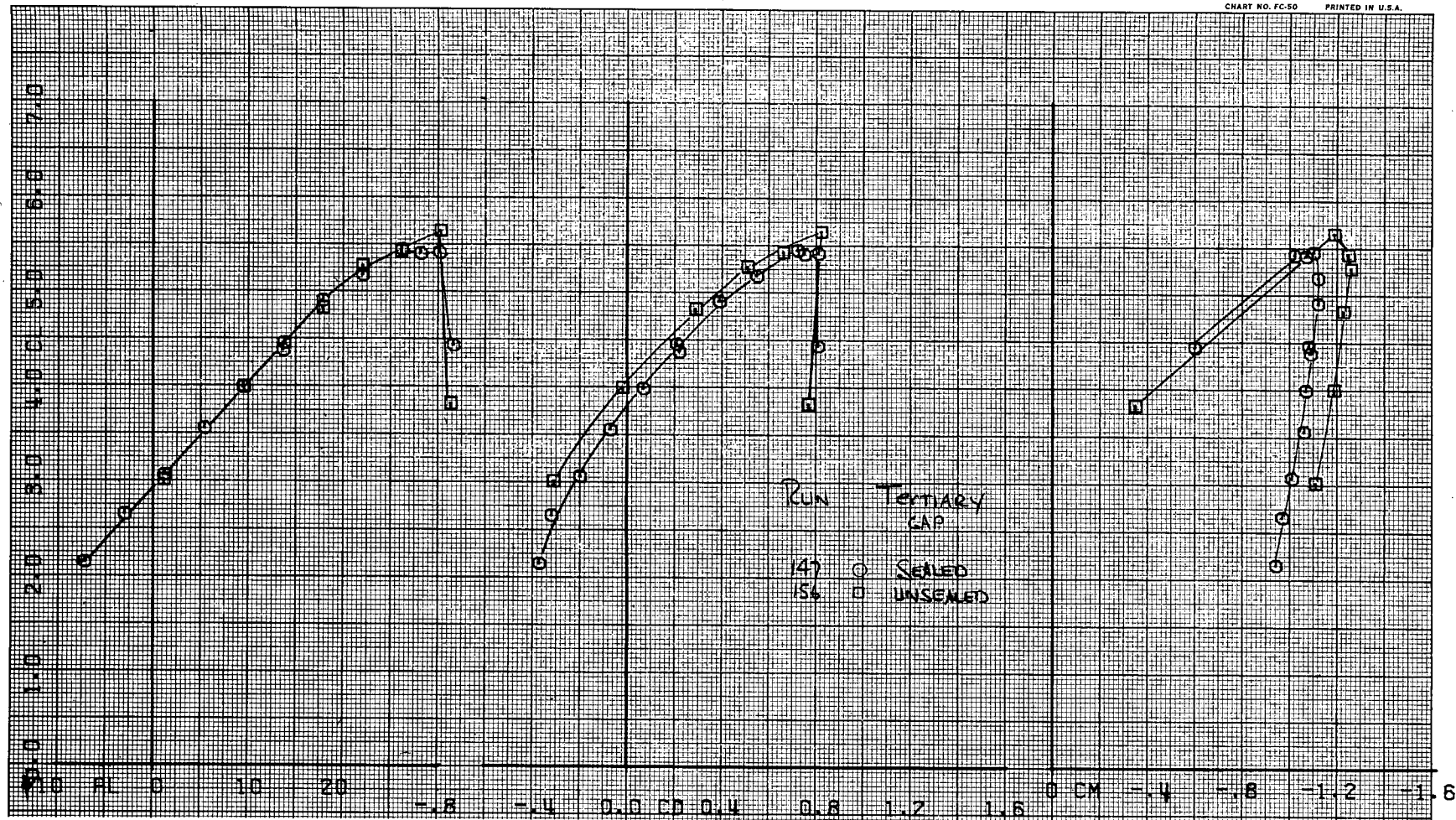
Figure 3.- Effect of sealing the augmentor tertiary gap on the longitudinal aerodynamic characteristics with horizontal tail removed; $\delta_f = 41.1^\circ$ and $\delta_s = 60^\circ$ (mod to stb'd)

FIRST RUN IS 147.

COMPL0T.

OMNIGRAPHIC.

HOUSTON INSTRUMENT
DIVISION OF MATHCO-LEONARD®
BELLAIRE, TEXAS
CHART NO. FC-50 PRINTED IN U.S.A.



(b) $C_{J_I} = .77$

Figure 3.- Continued.

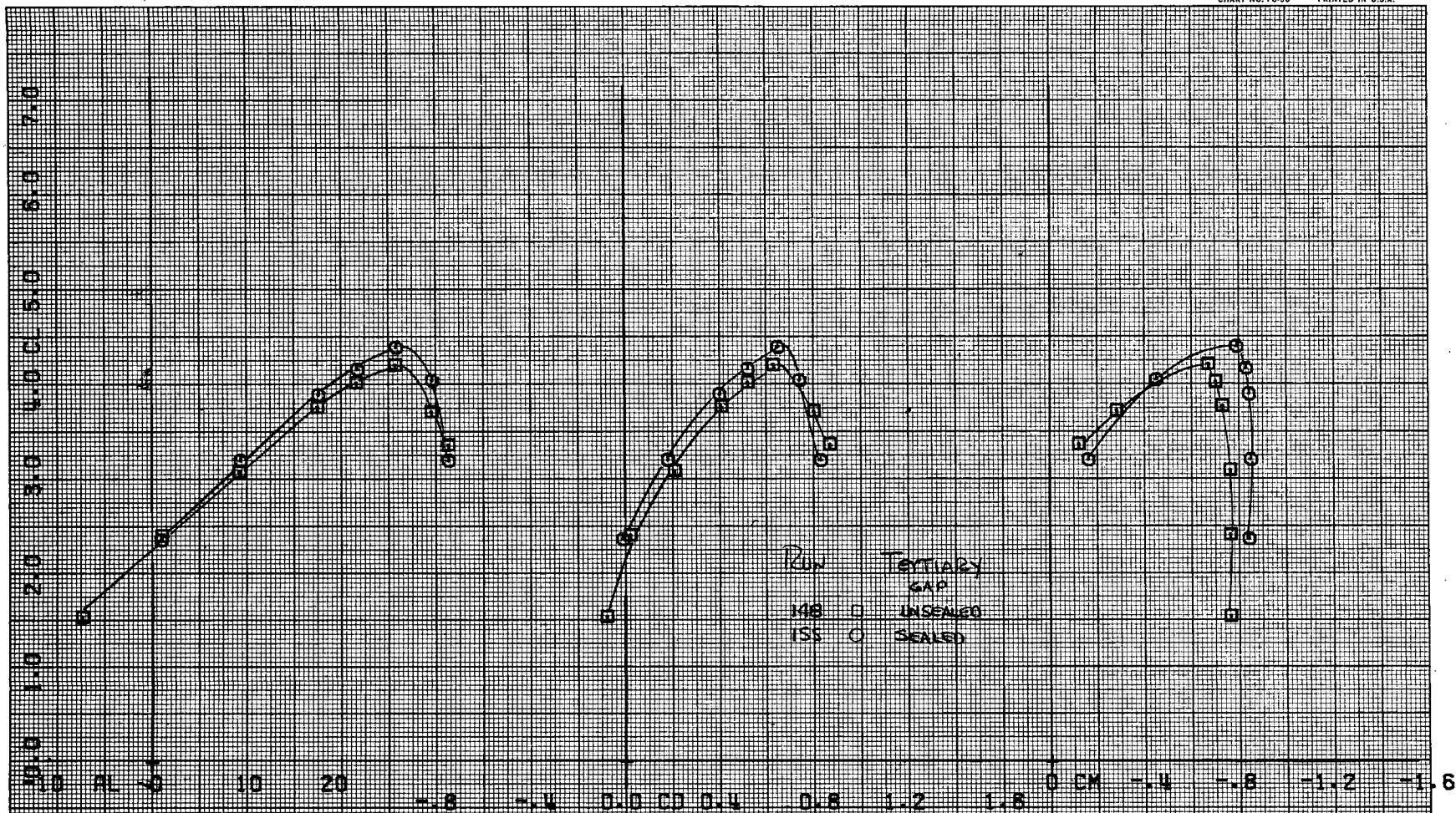
FIRST RUN IS 155.

COMPLÖT™

OMNIGRAPHIC™

HOUSTON INSTRUMENT
DIVISION OF MARLBOROUGH®
BELLAIRE, TEXAS

CHART NO. FC-50 PRINTED IN U.S.A.



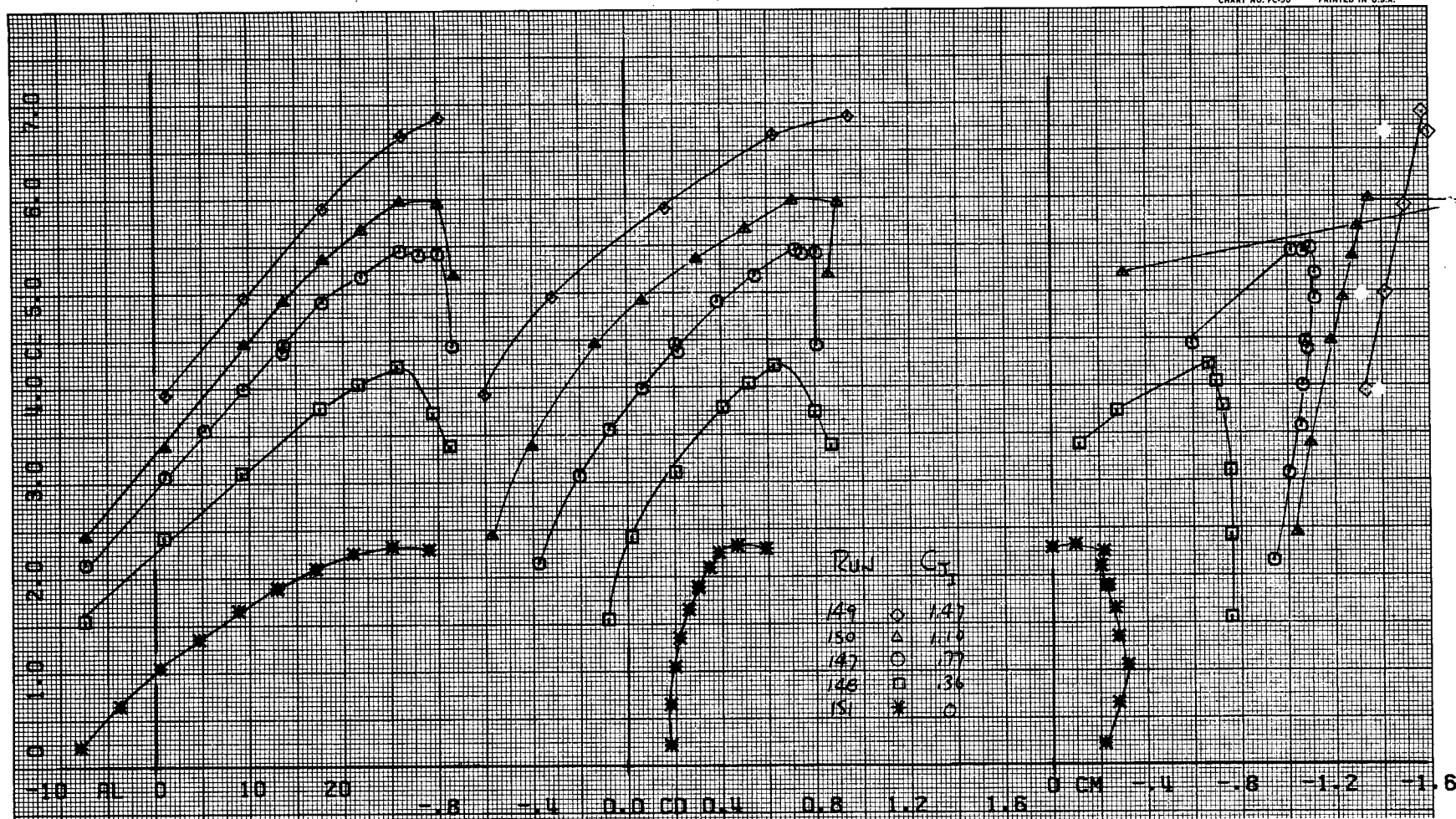
(c) $C_{J_I} = .36$

Figure 3 .- Continued.

FIRST RUN IS 147.

COMPLÖT™

OMNIGRAPHIC™

HOUSTON INSTRUMENT
DIVISION OF INSTRUMENT LOGIC®
BELLAIRE, TEXAS
CHART NO. FC-50 PRINTED IN U.S.A.

(d) Effect of C_{JI} with tertiary gap sealed
Figure 3 .- Concluded.

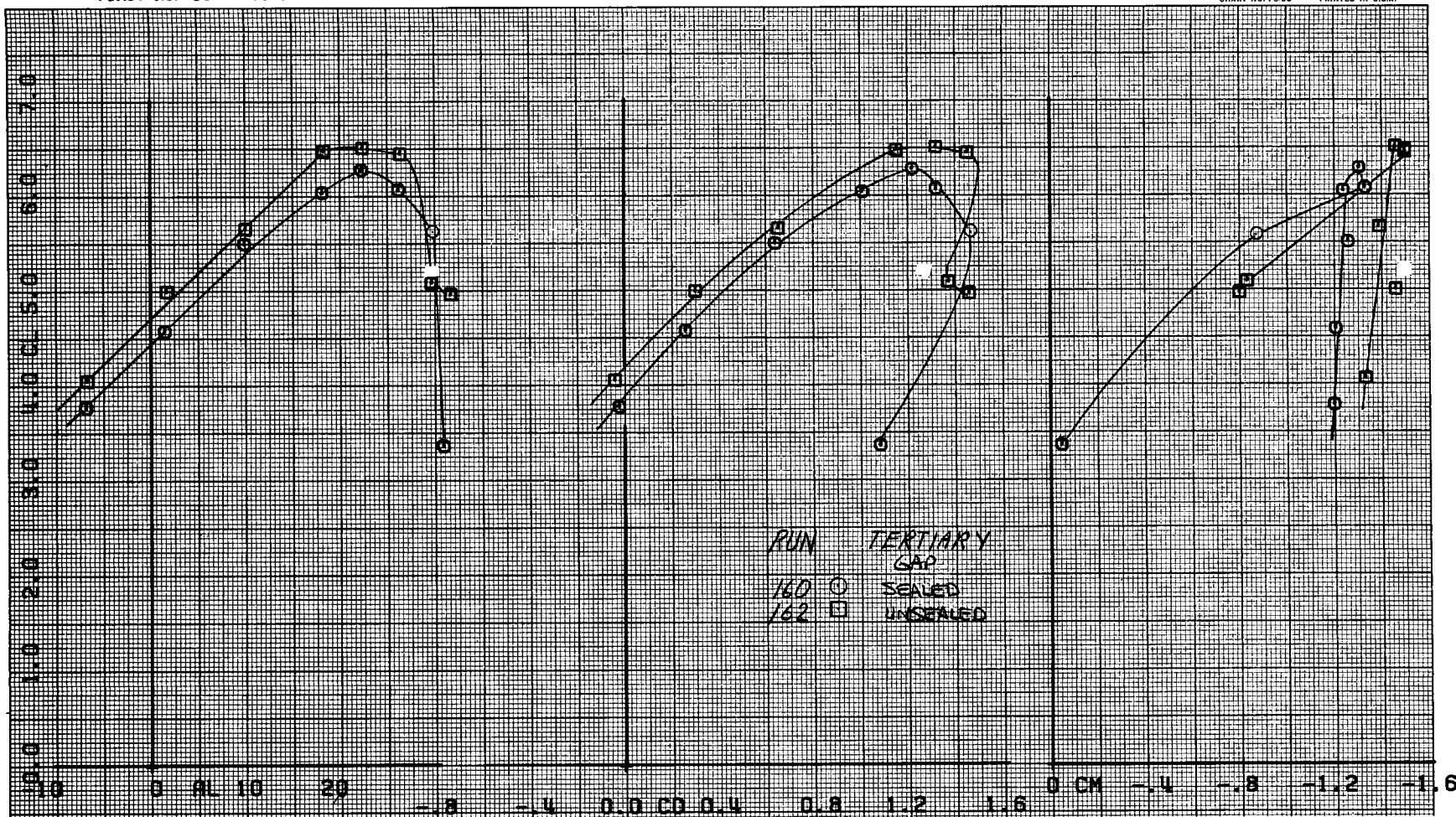
FIRST RUN IS 160.

COMPLÖT™

OMNIGRAPHIC™

HOUSTON INSTRUMENT
DIVISION OF BARNES-ROE, INC.
BELLARE, TEXAS

CHART NO. FC-50 PRINTED IN U.S.A.



(a) $C_{J_I} = 1.10$

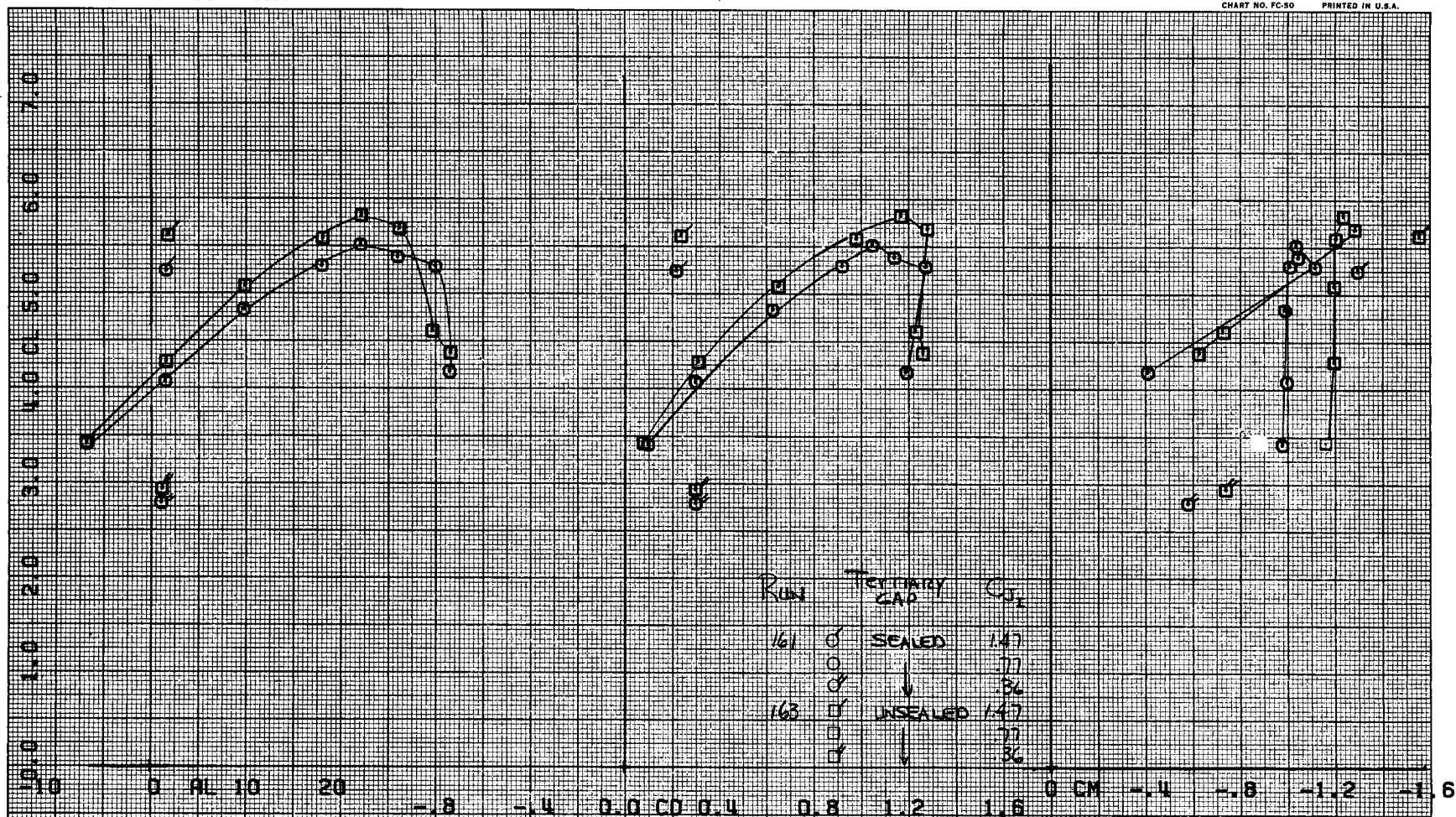
Figure 4.- Effect of sealing augmentor tertiary gap on longitudinal aerodynamic characteristics with horizontal tail removed; $\delta_f = 70.6^\circ$ and $\delta_s = 60^\circ$ (mod to stb'd)

FIRST RUN JS 161.

COMPLÖT_{TM}

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HOUSTON INSTRUMENT
DIVISION OF BAKER & LYONS
BELLAIRE, TEXAS
CHART NO. FC-50 PRINTED IN U.S.A.



(b) $C_{J_I} = .36, .77$ and 1.47

Figure 4.- Concluded.

FIRST RUN IS 2.

COMPLÖT™

OMNIGRAPHIC™

HOUSTON INSTRUMENT
DIVISION OF BAUGHN & SONS
BELLAIRE, TEXAS
CHART NO. FC-50 PRINTED IN U.S.A.

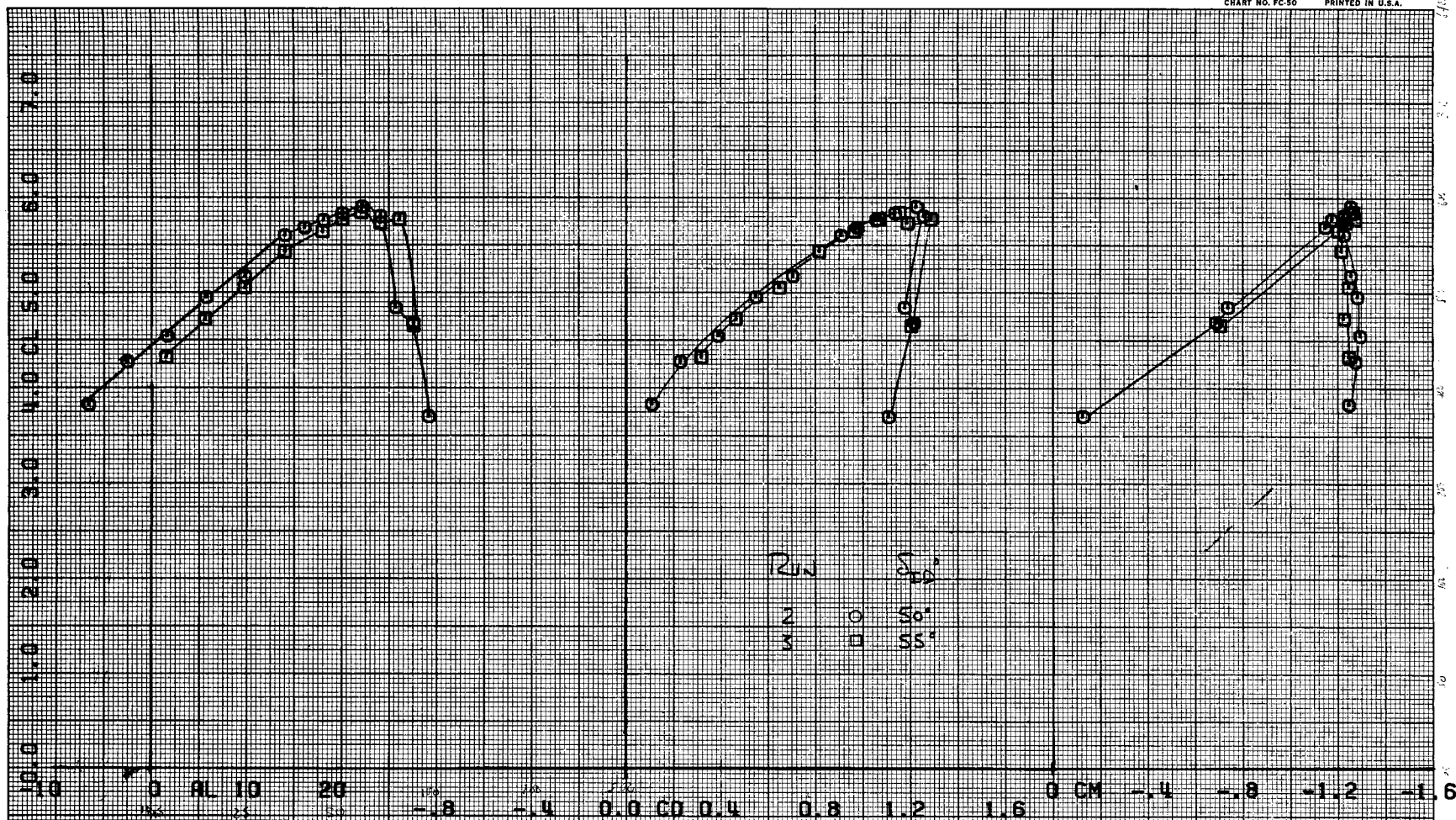


Figure 5.- Effect of augmentor intake door deflection on longitudinal aerodynamic characteristics with horizontal tail removed;

FIRST RUN IS 131.

COMPLOT™

OMNIGRAPHIC™

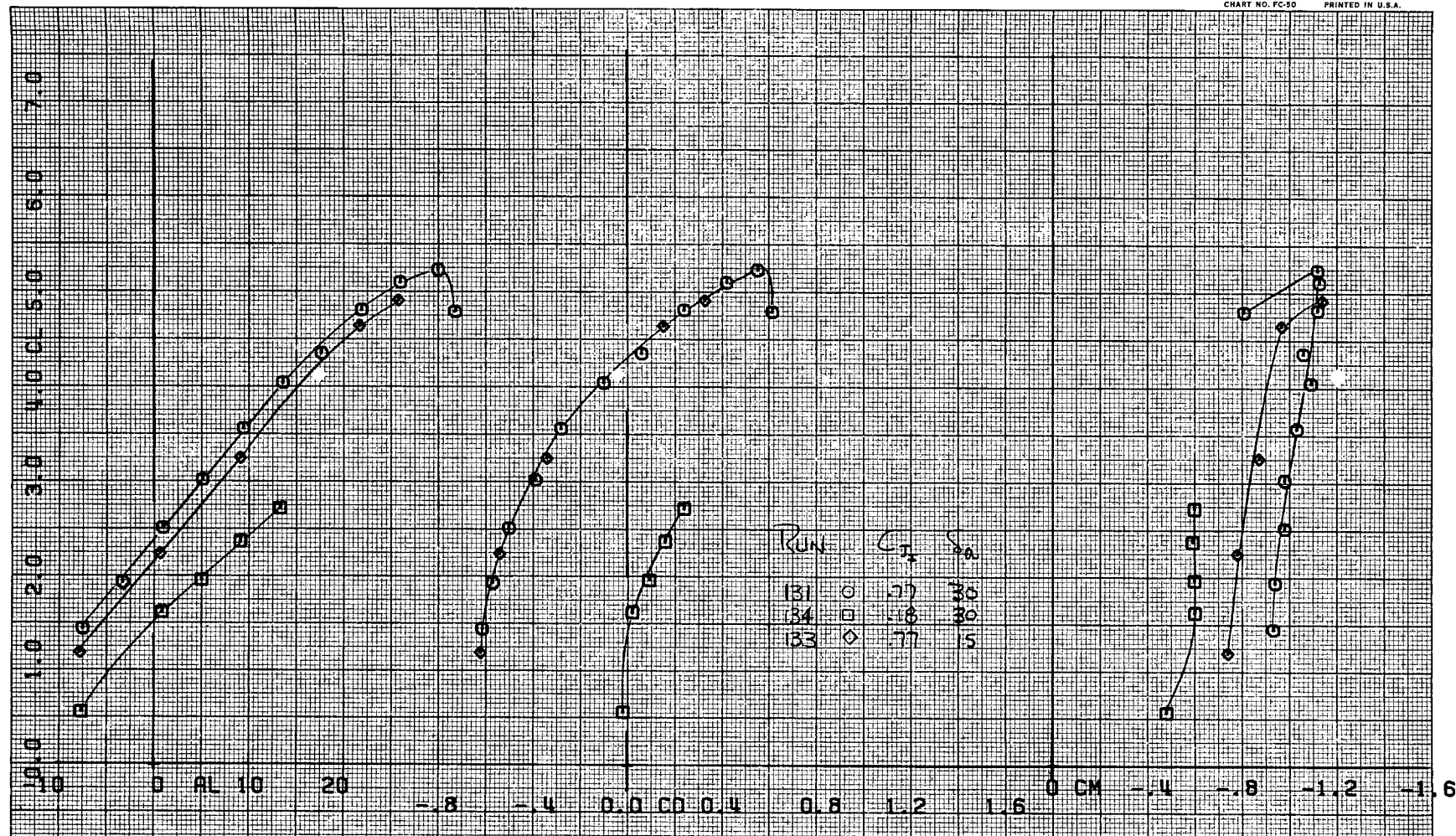
HOUSTON INSTRUMENT
DIVISION OF BUSHNELL CORP.
BELLAIRE, TEXAS
CHART NO. PC-50 PRINTED IN U.S.A.

Figure 6.- Effect of symmetrical aileron deflection on longitudinal aerodynamic characteristics with horizontal tail removed; $\delta_f = 31.8^\circ$, $\delta_s = 60^\circ$ (mod to stb'd).

FIRST RUN IS 20.

COMPLÖT.

OMNIGRAPHIC.

HOUSTON INSTRUMENT
DIVISION OF BAKER CORP.
BELLAIRE, TEXAS
CHART NO. FC-50 PRINTED IN U.S.A.

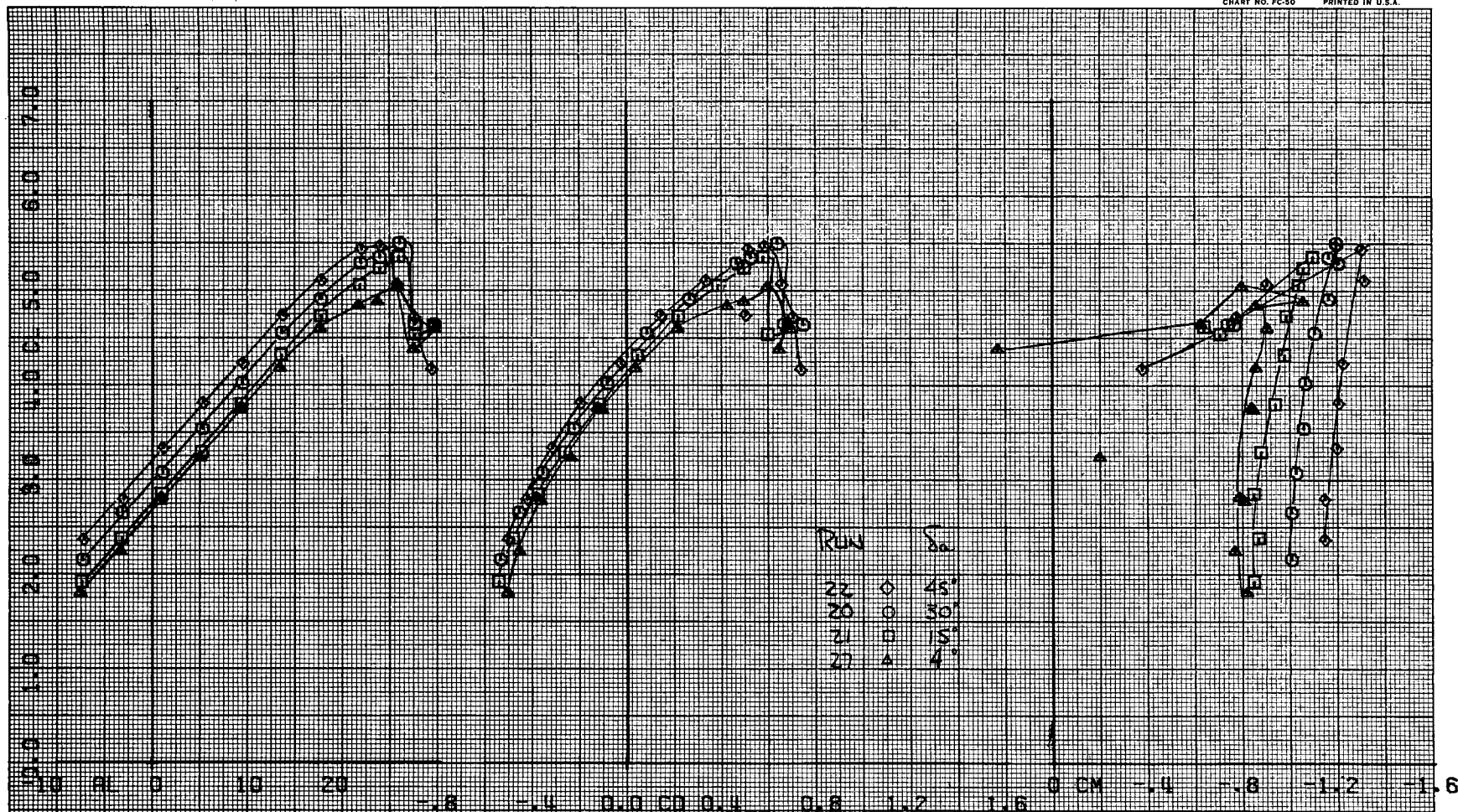
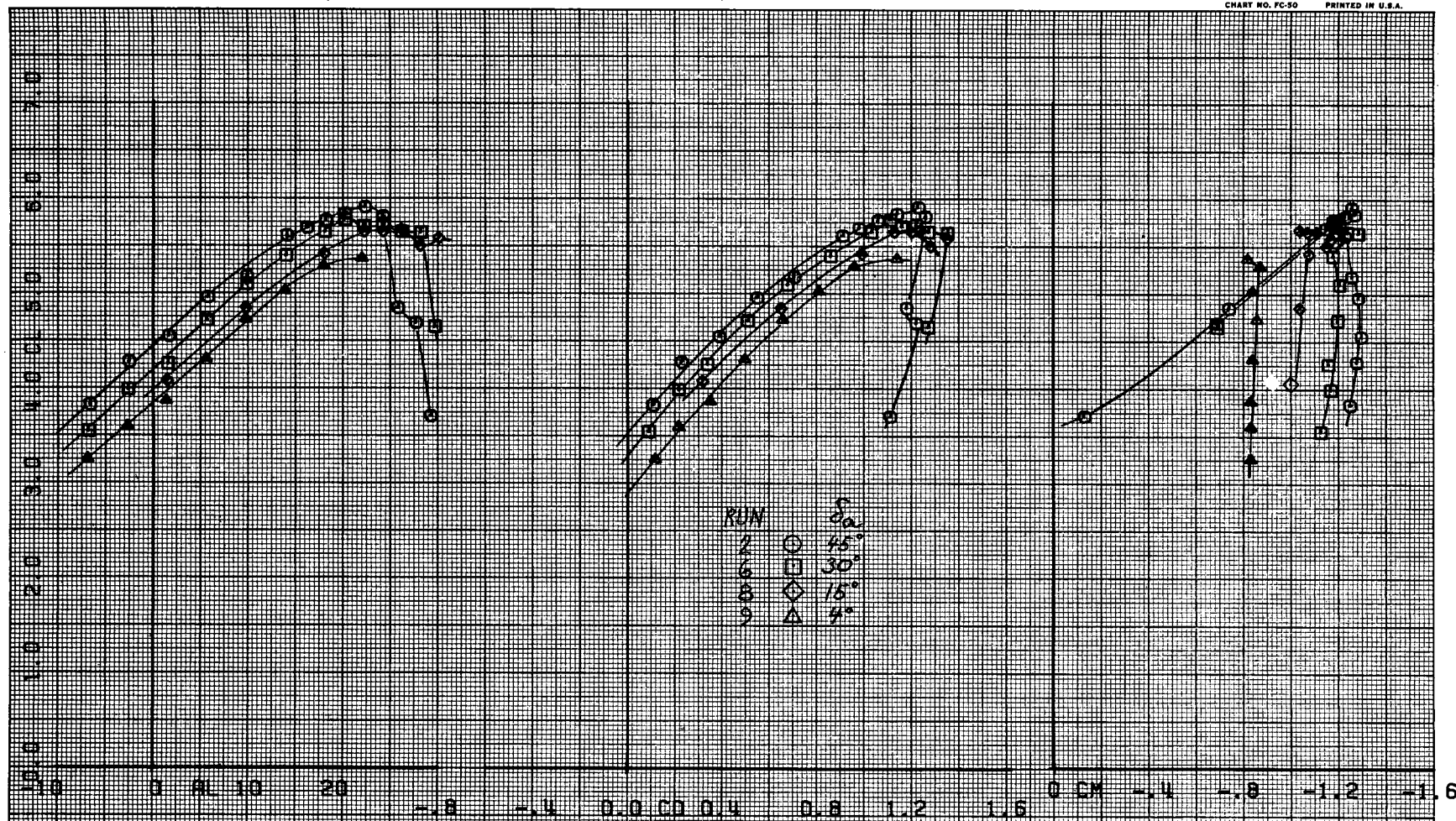


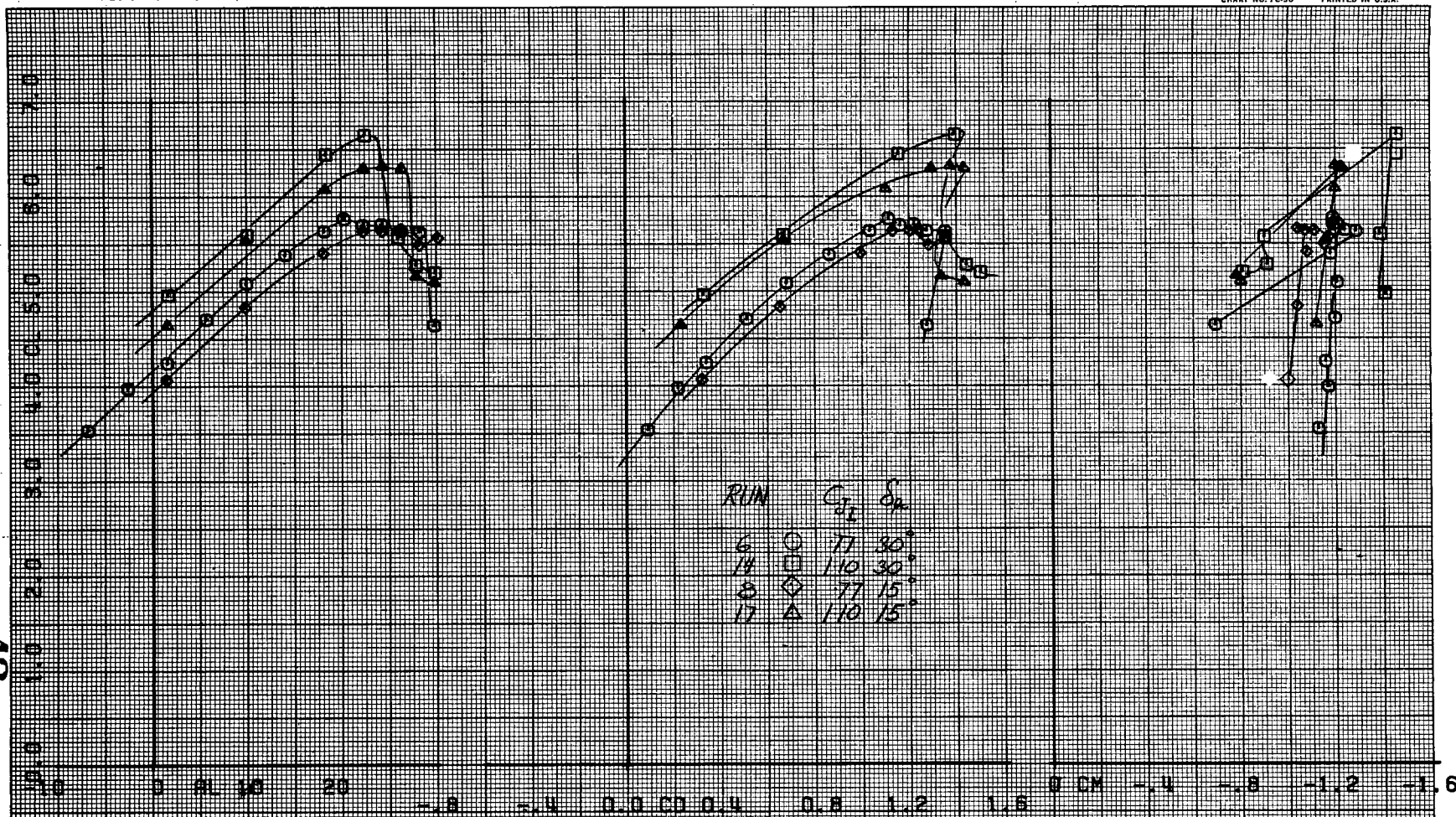
Figure 7.- Effect of symmetrical aileron deflection on longitudinal aerodynamic characteristics with horizontal tail removed; $\delta_f = 41.1^\circ$, $\delta_s = 60^\circ$ (mod to stb'd).



(a) $C_{J_I} = .77$, $\delta_s = 60^\circ$

Figure 8.- Effect of symmetrical aileron deflection on longitudinal aerodynamic characteristics with horizontal tail removed; $\delta_f = 70.6^\circ$.

42



(b) $C_{J_I} = .77$ and 1.10 , $\delta_s = 60^\circ$

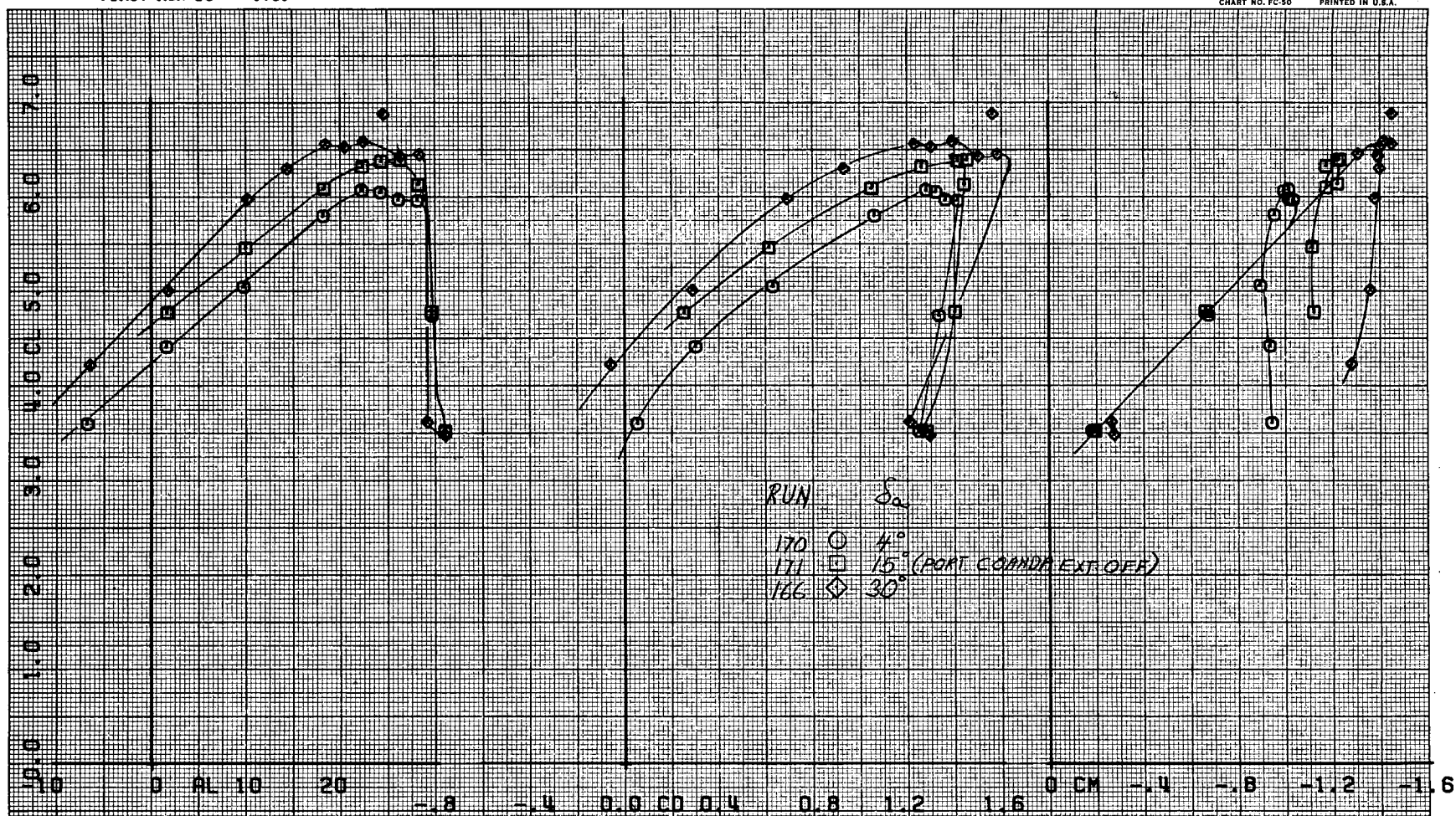
Figure 8.- Continued.

FIRST RUN IS 170.

COMPLÖT_{TM}

OMNIGRAPHIC_{TM}

HOUSTON INSTRUMENT
DIVISION OF MARSHALLS
BELLAIRE, TEXAS
CHART NO. FC-50 PRINTED IN U.S.A.



(c) $C_{J_I} = 1.10$ and $\delta_s = 50^\circ$

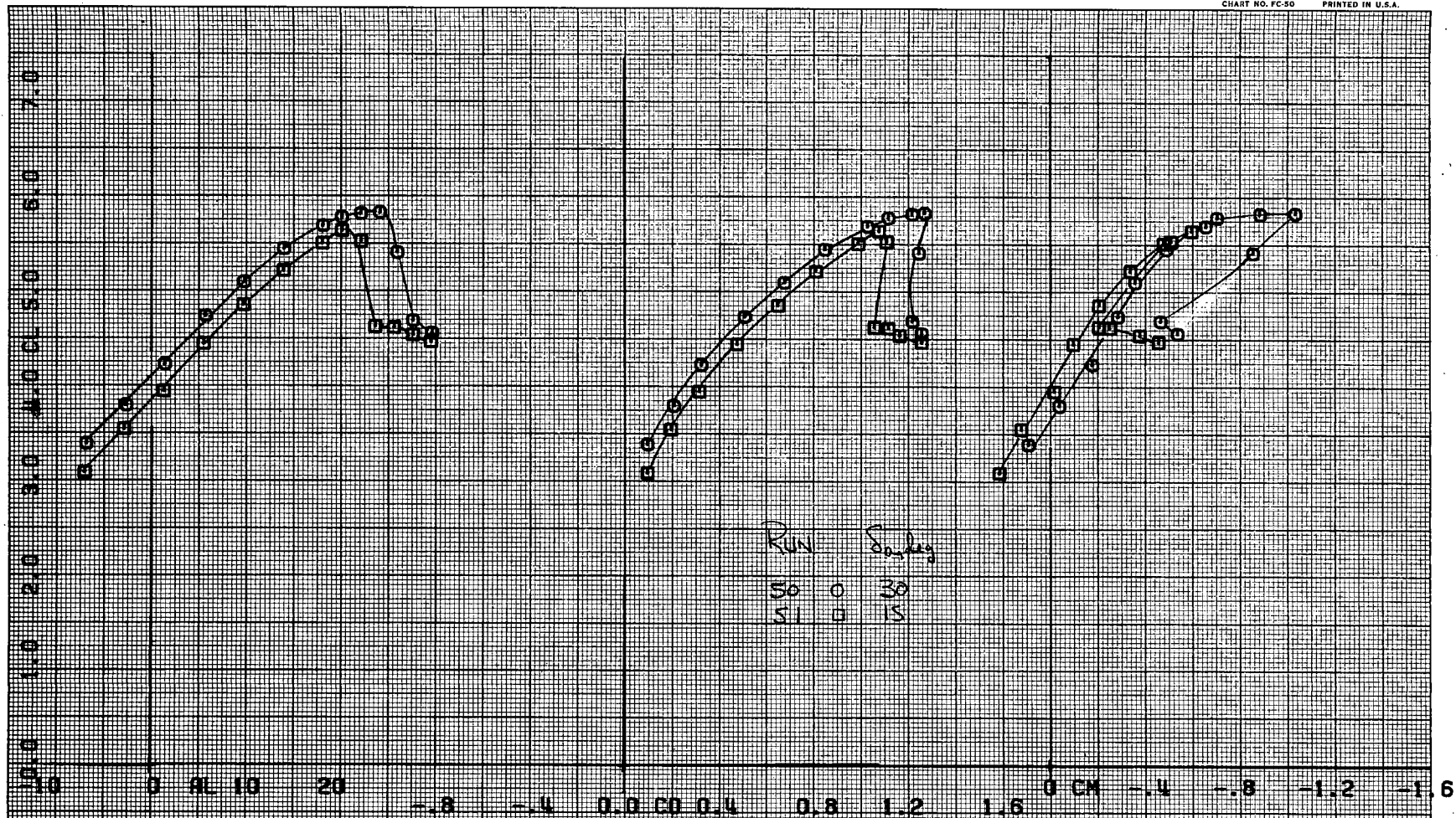
Figure 8.- Concluded.

FIRST RUN IS 50.

COMPLÖT_{TM}

OMNIGRAPHIC_{TM}

HOUSTON INSTRUMENT
DIVISION OF BAUGHN & LAMB
BELLAIRE, TEXAS
CHART NO. FC-50 PRINTED IN U.S.A.



(a) $\delta_s = 60^\circ$

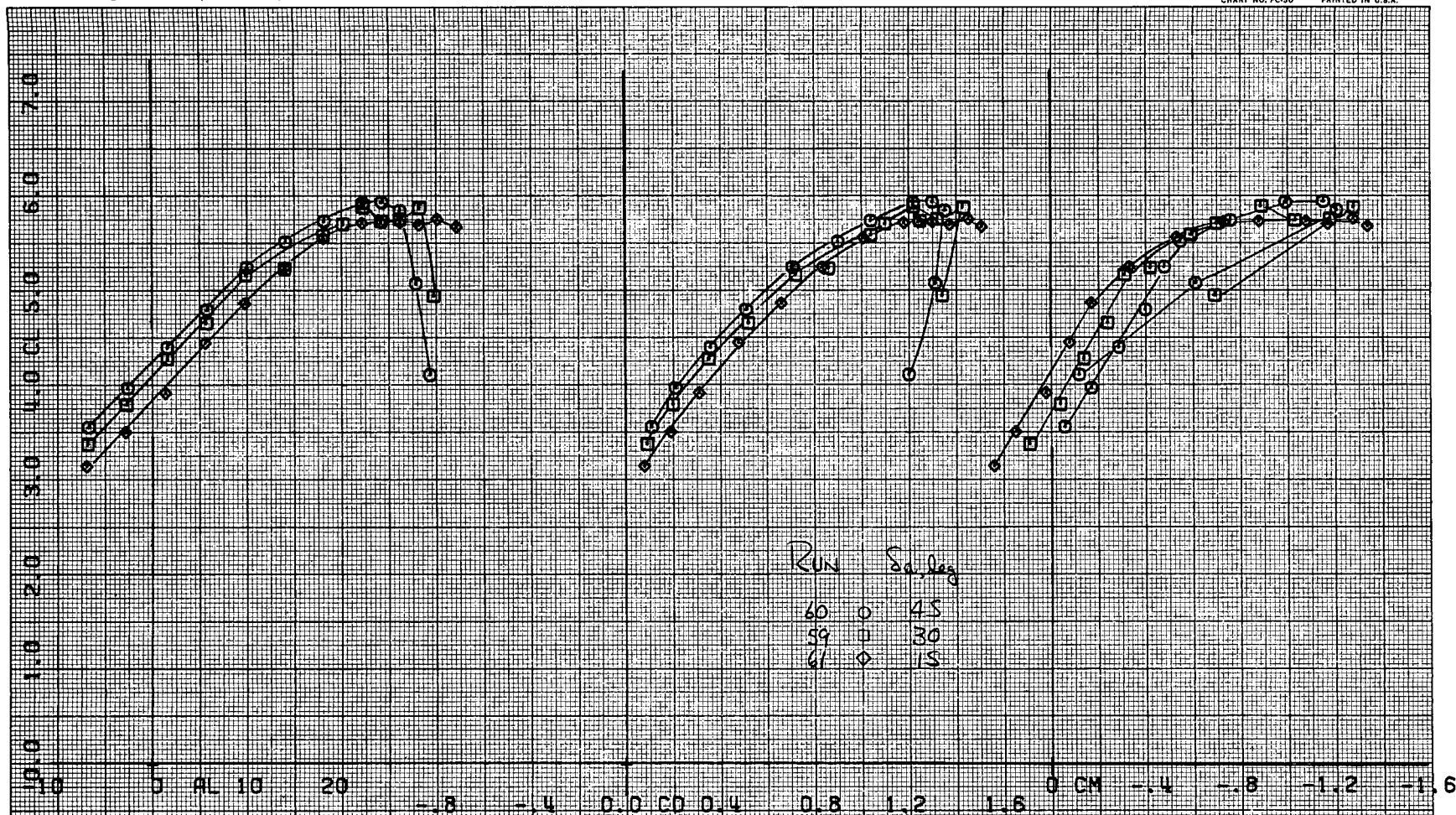
Figure 9.- Effect of symmetrical aileron deflection on longitudinal aerodynamic characteristics with horizontal tail installed; $\delta_f = 70.6^\circ$, $C_{J_I} = .77$.

FIRST RUN 15 60.

COMPLÖT.

OMNIGRAPHIC.

HOUSTON INSTRUMENT
DIVISION OF BARNHILL CORP.
BELLAIRE, TEXAS
CHART NO. FC-50 PRINTED IN U.S.A.



(b) $\delta_s = 60^\circ$ (mod to stb'd)

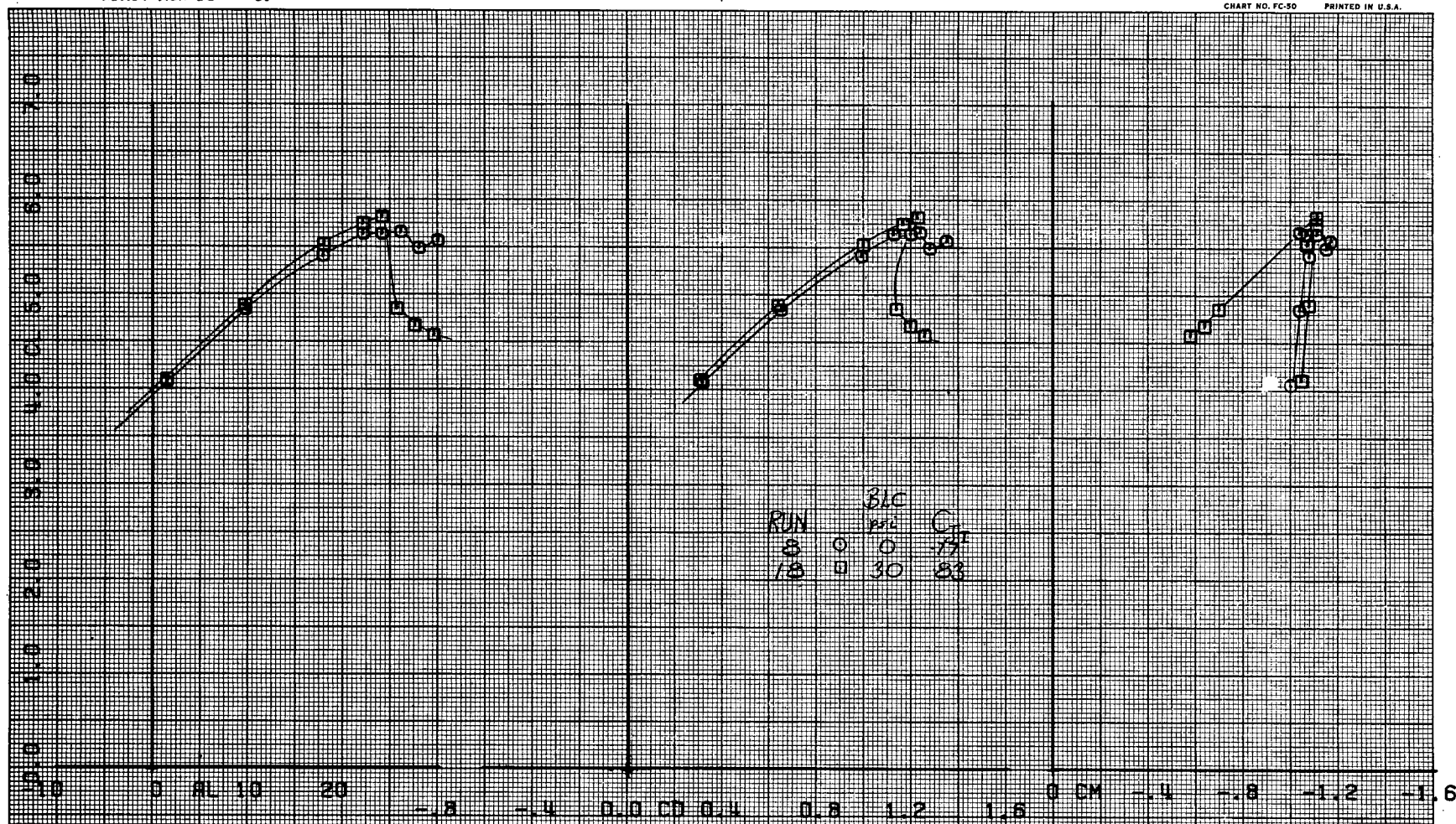
Figure 9.- Concluded.

FIRST RUN IS 8.

COMPLÖT_{TM}

OMNIGRAPHIC_{TM}

HOUSTON INSTRUMENT
DIVISION OF BELL & HOWELL
BELLAIRE, TEXAS
CHART NO. FC-50 PRINTED IN U.S.A.



(a) $C_{J_I} = .77$

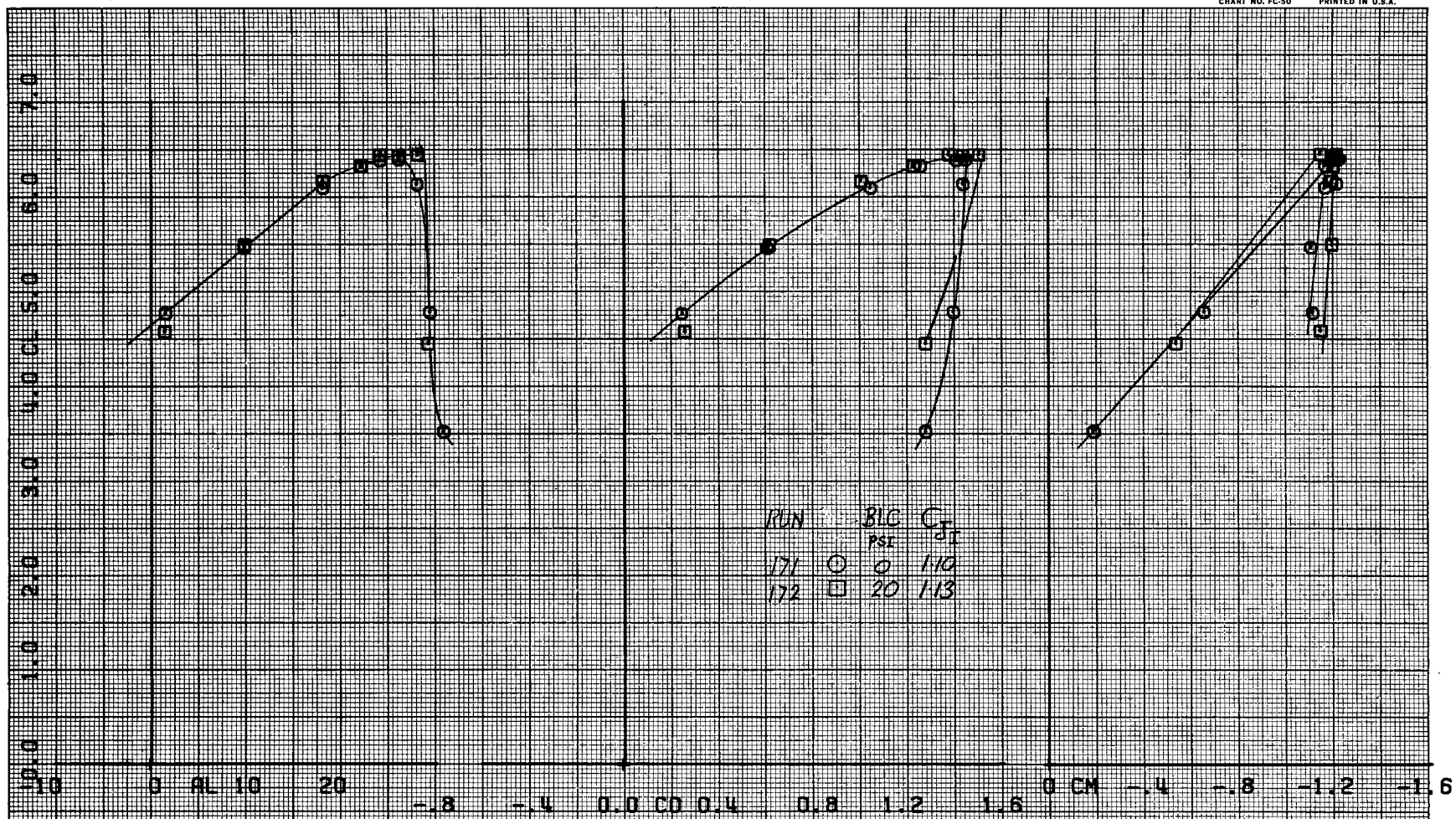
Figure 10.- Effect of fuselage BLC on longitudinal aerodynamic characteristics; $\delta_f = 70.6^\circ$.

FIRST RUN IS 171.

COMPLÖT_{TM}

OMNIGRAPHIC_{TM}

HOUSTON INSTRUMENT
DIVISION OF BAKER & LYONS
BELLAIRE, TEXAS
CHART NO. FC-50 PRINTED IN U.S.A.



(b) $C_{JI} = 1.10$, $\delta_s = 50^\circ$

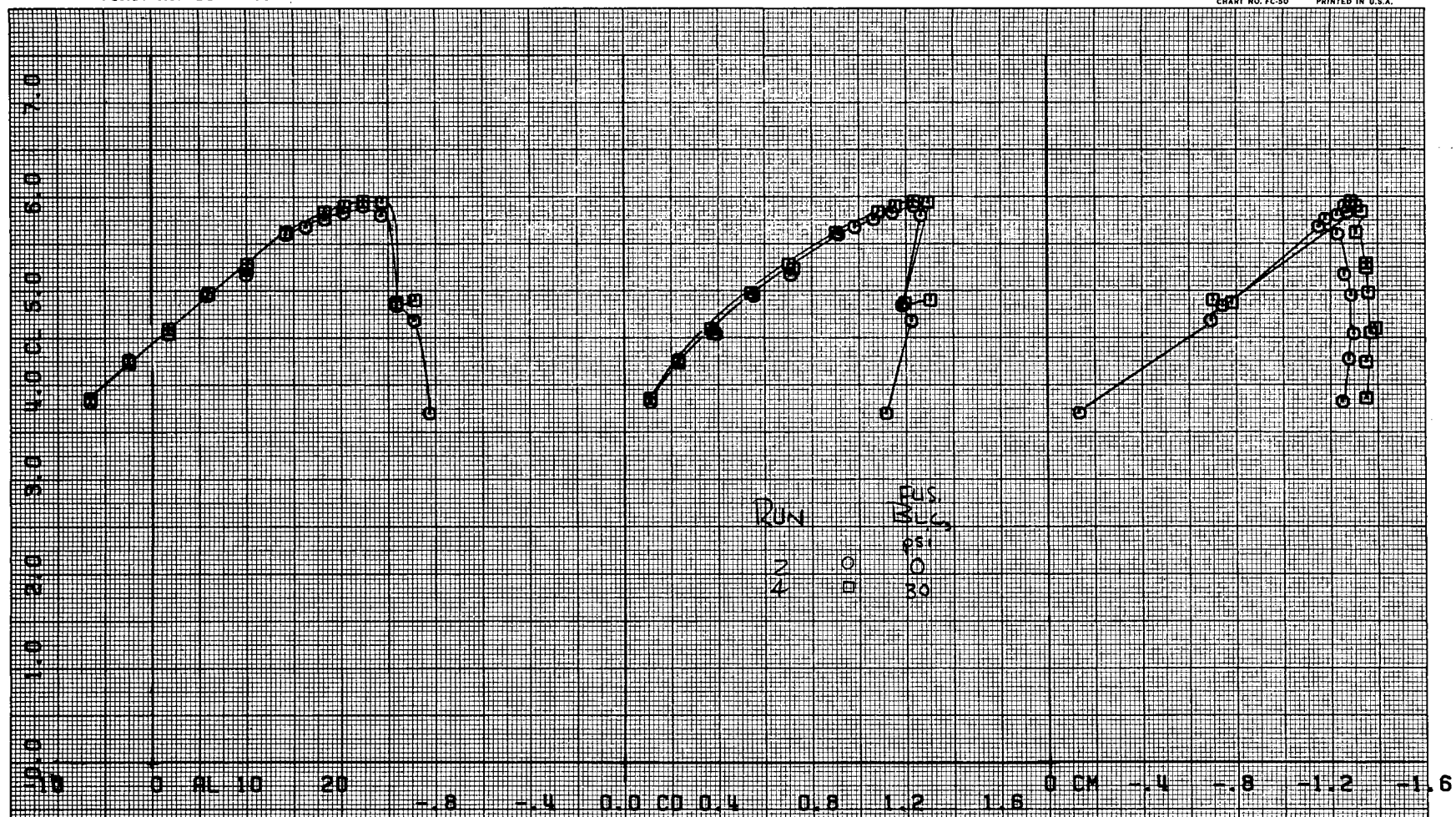
Figure 10.- Continued

FIRST RUN IS 2.

COMPLØT™

OMNIGRAPHIC™

HOUSTON INSTRUMENT
DIVISION OF MORGAN & LUMBER®
BELLAIRE, TEXAS
CHART NO. FC-50 PRINTED IN U.S.A.



(c) $C_{J_I} = .77, \delta_s = 60^\circ$

Figure 10.- Continued.

FIRST RUN IS 64.

COMPLÖT.

OMNIGRAPHIC.

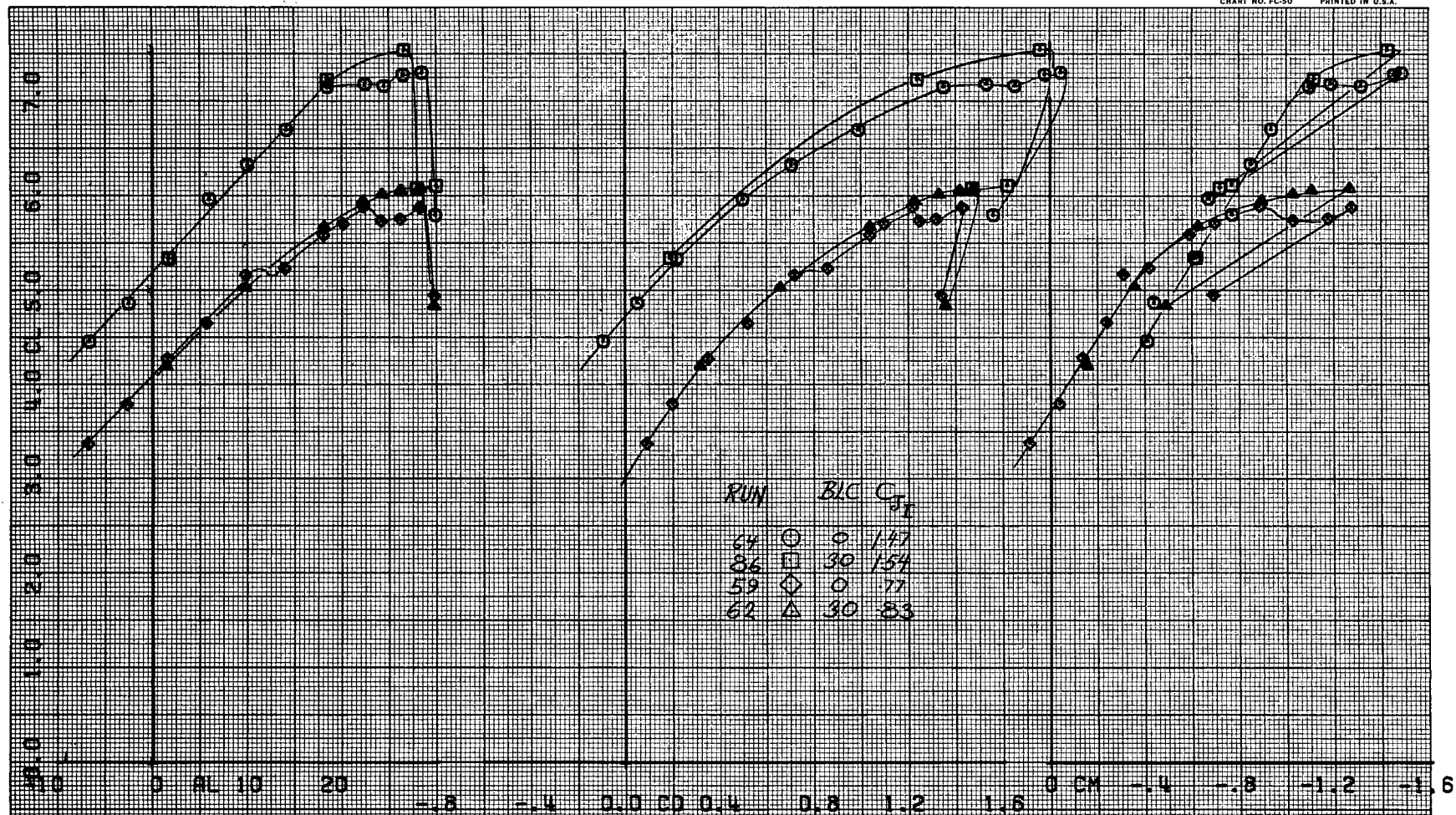
HOUSTON INSTRUMENT
DIVISION OF BAIRD-ATLANTA
BELLAIRE, TEXAS
CHART NO. FC-50 PRINTED IN U.S.A.(d) $\delta_s = 60^\circ$ (mod to stb'd), horizontal tail installed

Figure 10.- Concluded.

FIRST RUN IS 14.

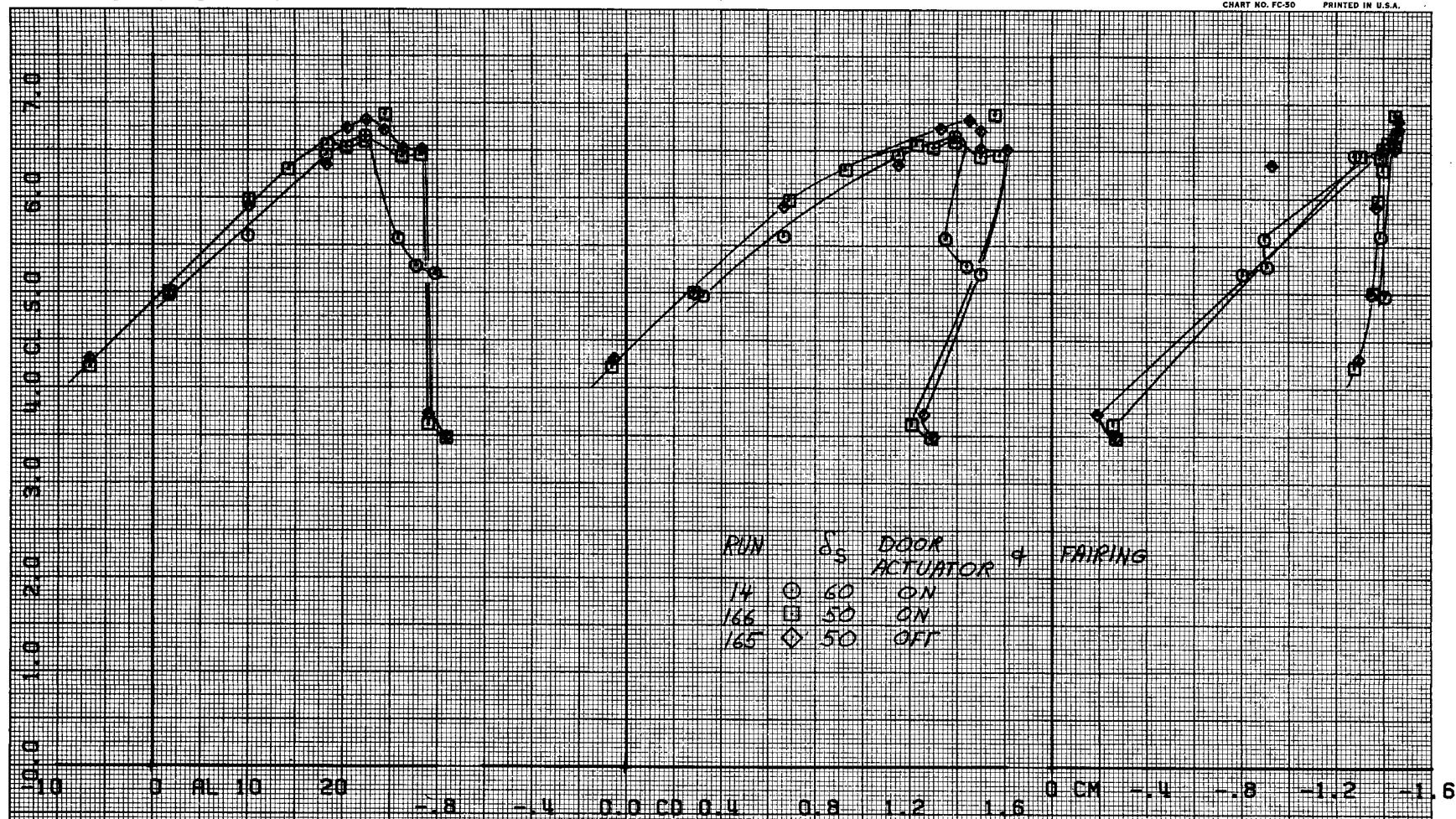
COMPLÖT_{TM}OMNIGRAPHIC_{TM}HOUSTON INSTRUMENT
DIVISION OF HARRIS-CORPORATION
DALLAS, TEXAS
CHART NO. FC-50 PRINTED IN U.S.A.(a) $\delta_s = 60^\circ$ and 50°

Figure 11.- The effect of intake door actuator fairing on longitudinal aerodynamic characteristics; $\delta_f = 70.6^\circ$.

FIRST RUN IS 139.

COMPLÖT_{TM}OMNIGRAPHIC_{TM}HOUSTON INSTRUMENT
DIVISION OF BARNES ENGINEERING
BELLAIRE, TEXAS

CHART NO. FC-50 PRINTED IN U.S.A.

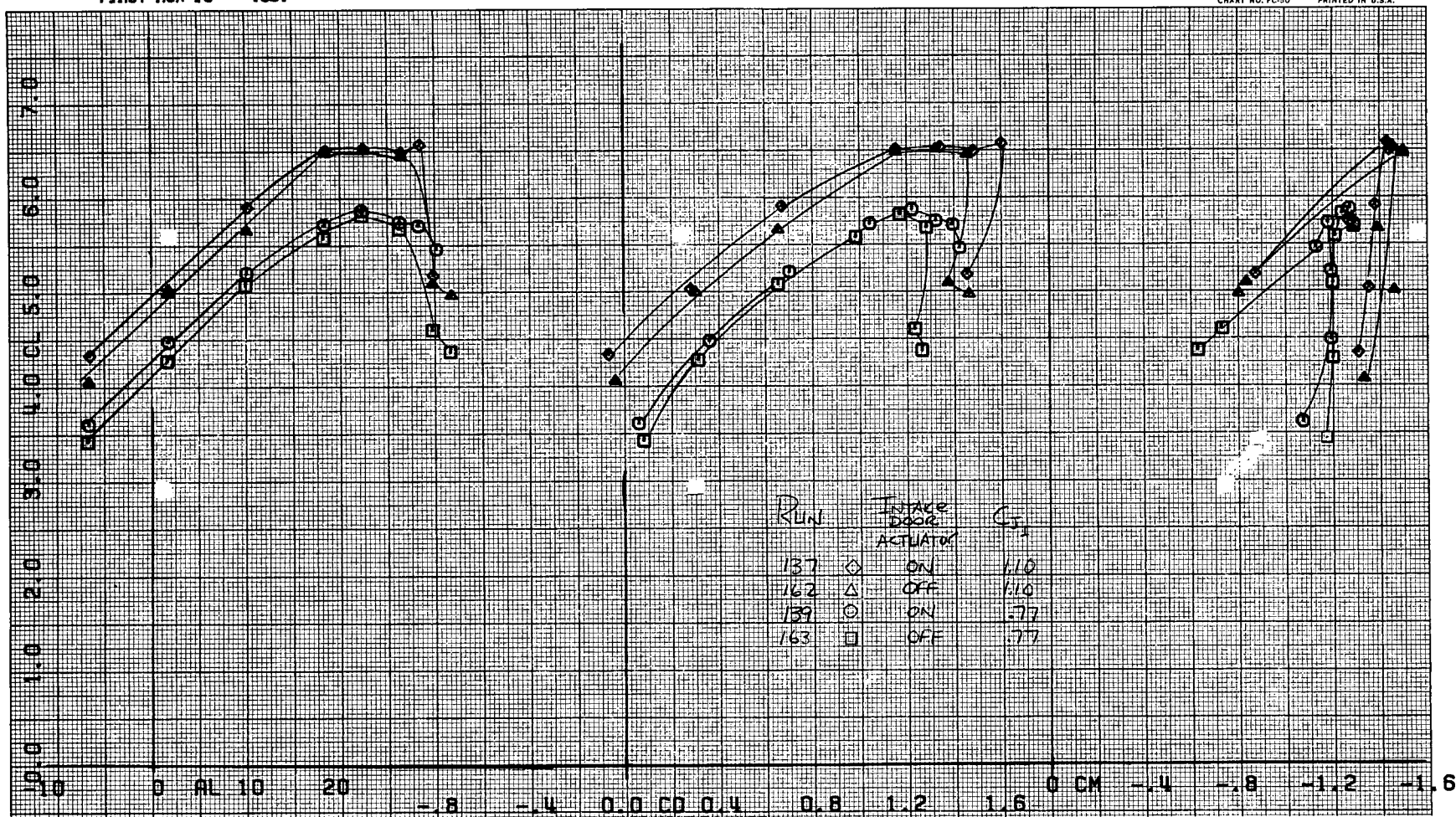
(b) $\delta_s = 60^\circ$ (mod to stb'd)

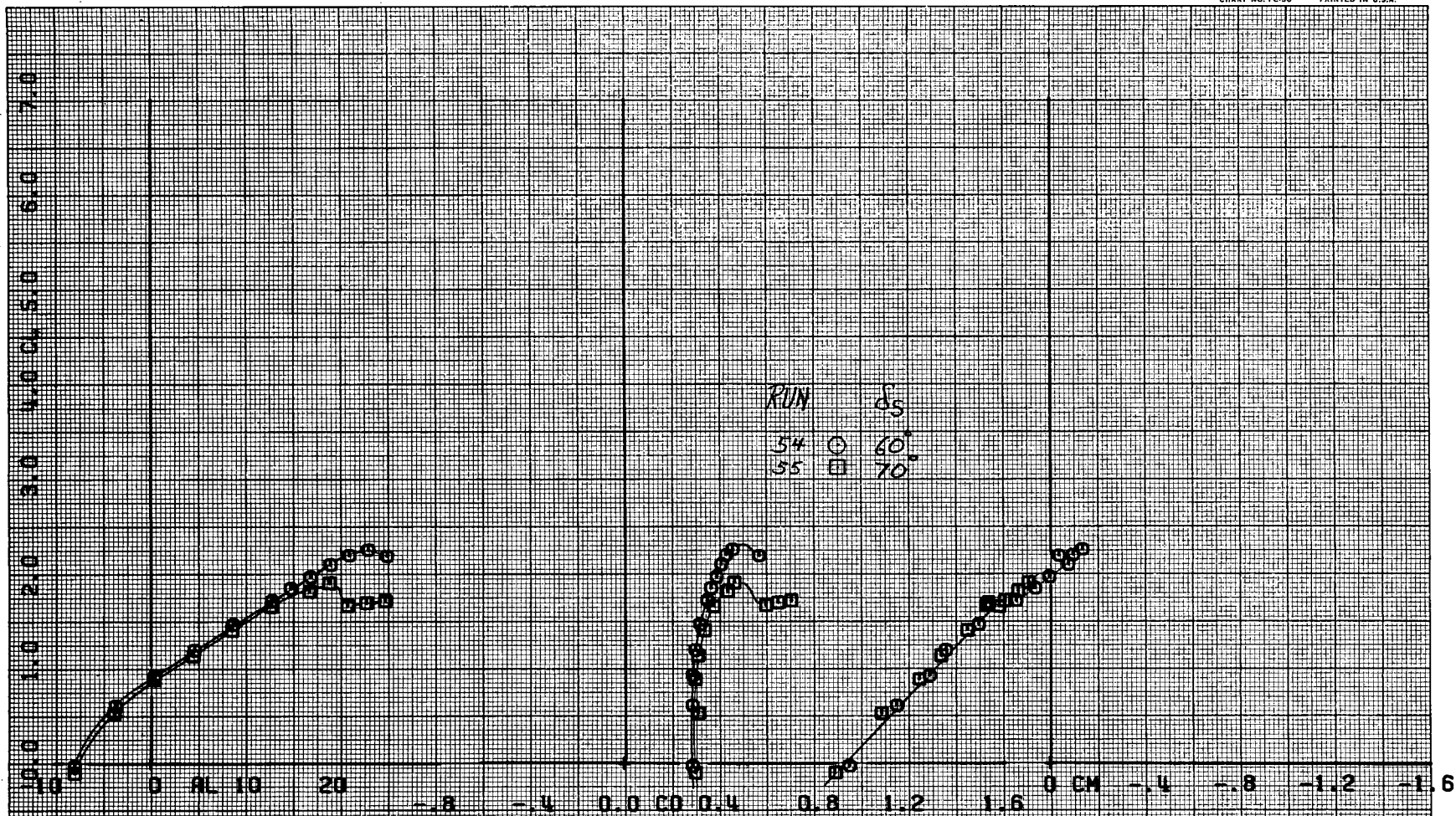
Figure 11.- Concluded.

FIRST RUN IS 54.

COMPLÖT₁₁

OMNIGRAPHIC₁₁

HOUSTON INSTRUMENT
DIVISION OF MORGENTHAU &
BELLAIRE, TEXAS
CHART NO. FC-50 PRINTED IN U.S.A.



(a) $C_{J_I} = 0$

Figure 12.- Effect of slat deflection on longitudinal aerodynamic characteristics with horizontal tail installed; $\delta_f = 70.6^\circ$.

FIRST RUN IS 50.

COMPLÖT™

OMNIGRAPHIC™

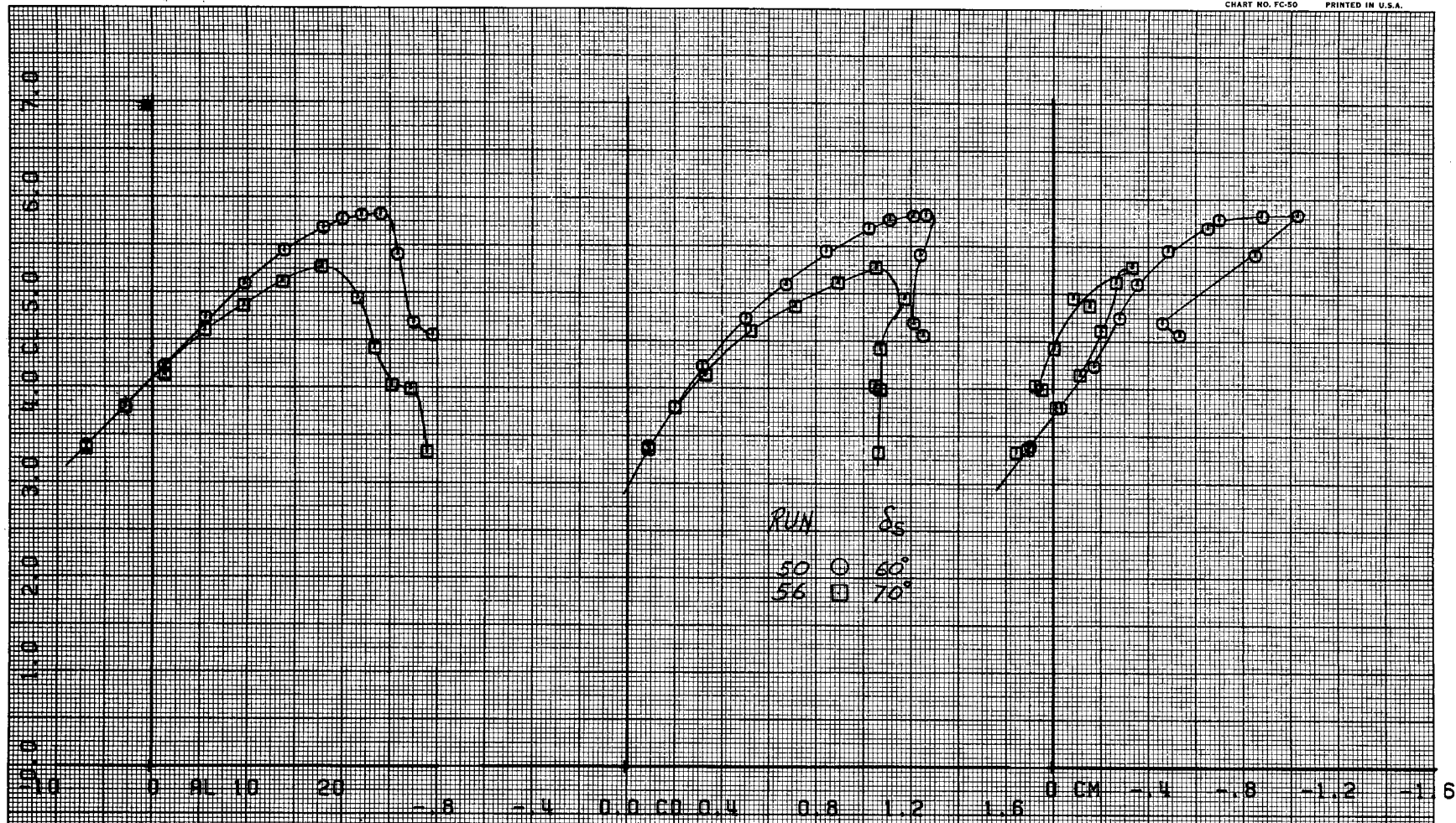
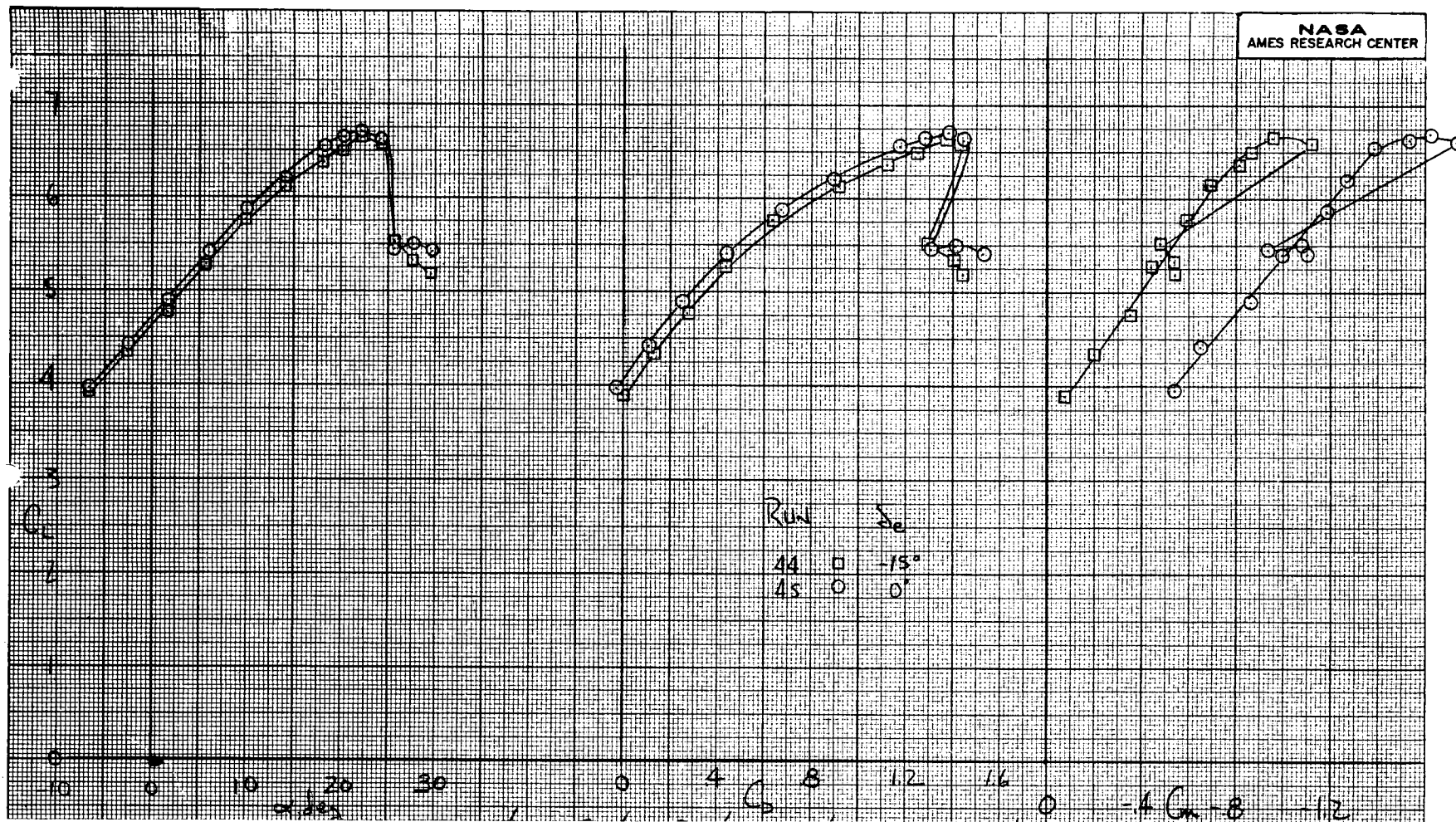
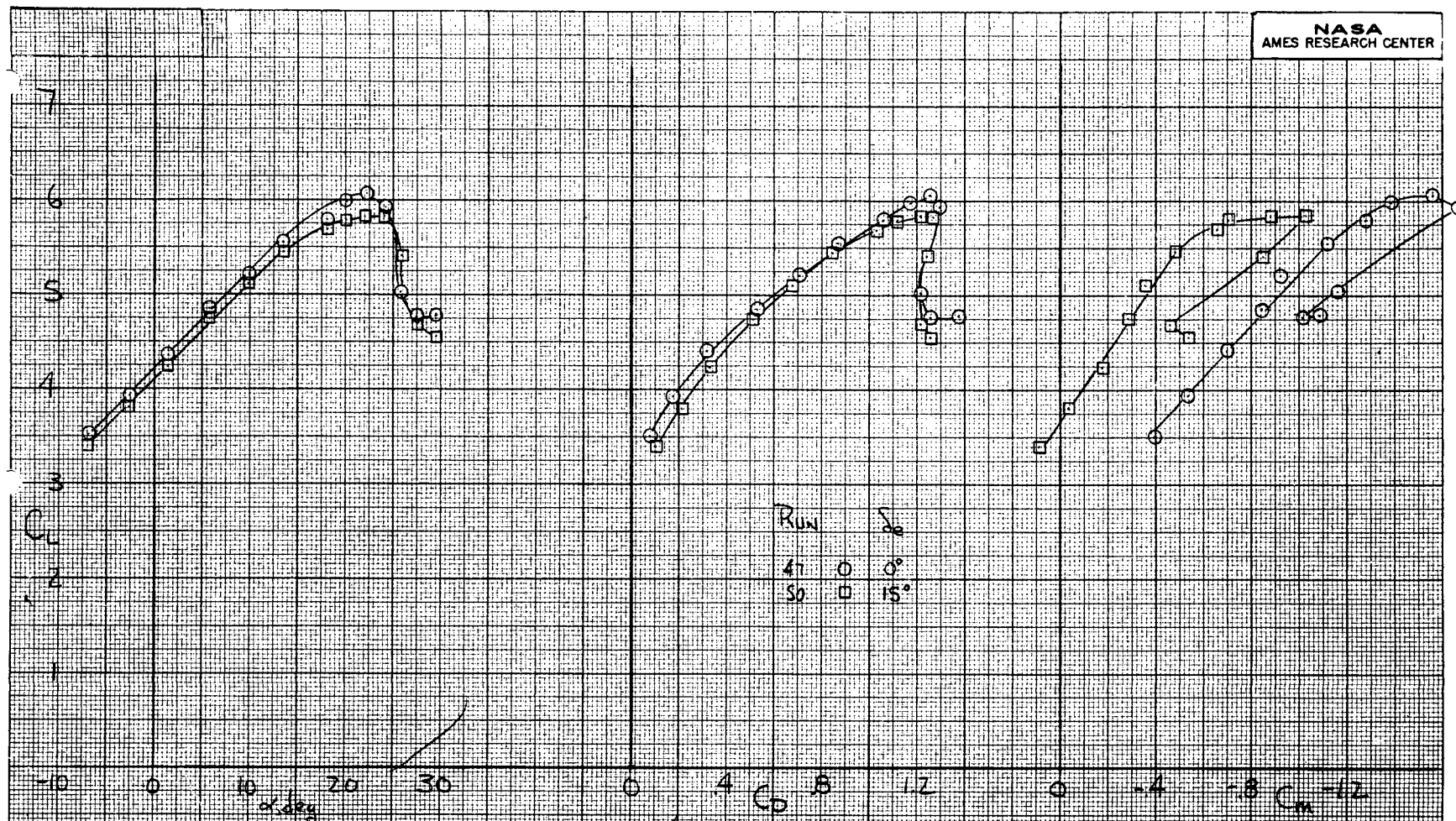
HOUSTON INSTRUMENT
DIVISION OF SAATCHI & SAATCHI
BELLAIRE, TEXAS
CHART NO. FC-50 PRINTED IN U.S.A.(b) $C_{JI} = .77$

Figure 12.- Concluded.



(a) $C_{J_I} = 1.10$, $i_t = -1^\circ$

Figure 13. - Effect of elevator deflection on longitudinal aerodynamic characteristics; $\delta_f = 70.6$.



(b) $C_{J_I} = .77$, $i_t = -1$

Figure 13.- Continued.

FIRST RUN 13 96.

COMPLOT.

OMNIGRAPHIC.

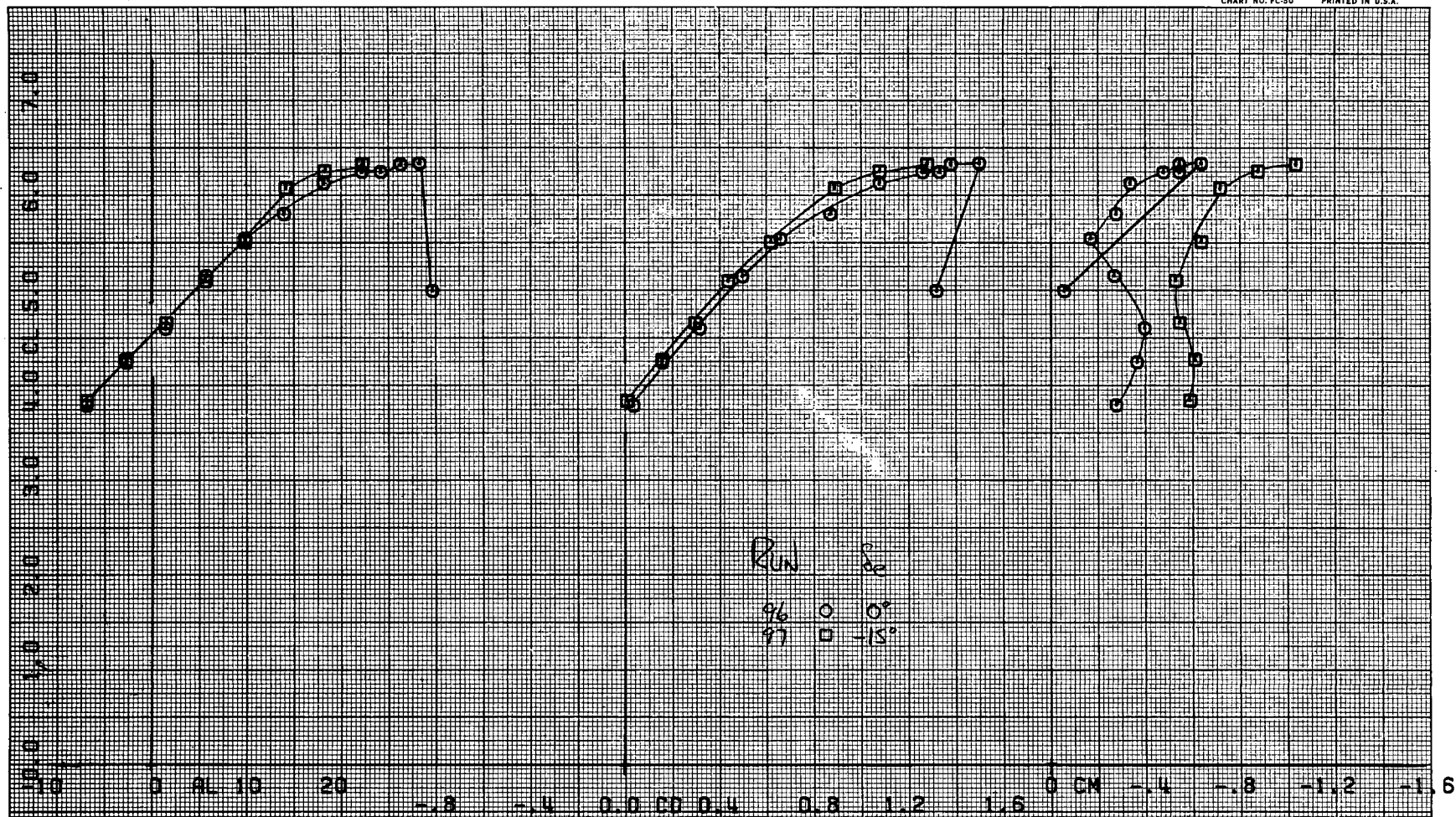
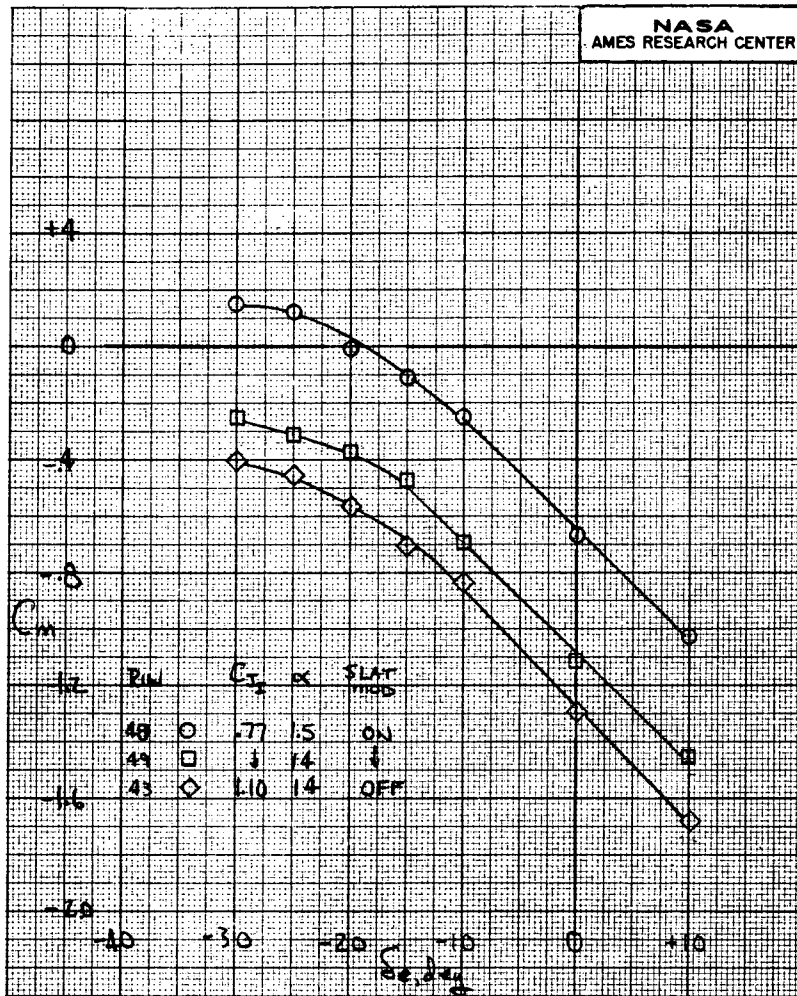
HOUSTON INSTRUMENT
DIVISION OF BAUGH & LOOSE
BELLAIRE, TEXAS
CHART NO. FC-50 PRINTED IN U.S.A.(c) $C_{J_I} = 1.10$, $i_t = -10.1^\circ$

Figure 13.- Continued.



(d) C_m vs. S_e

Figure 13.- Concluded.

FIRST RUN IS 66.

COMPLÖT™

OMNIGRAPHIC™

HOUSTON INSTRUMENT
DIVISION OF BRANCH ENGINEERING
BELLAIRE, TEXAS
CHART NO. FC-50 PRINTED IN U.S.A.

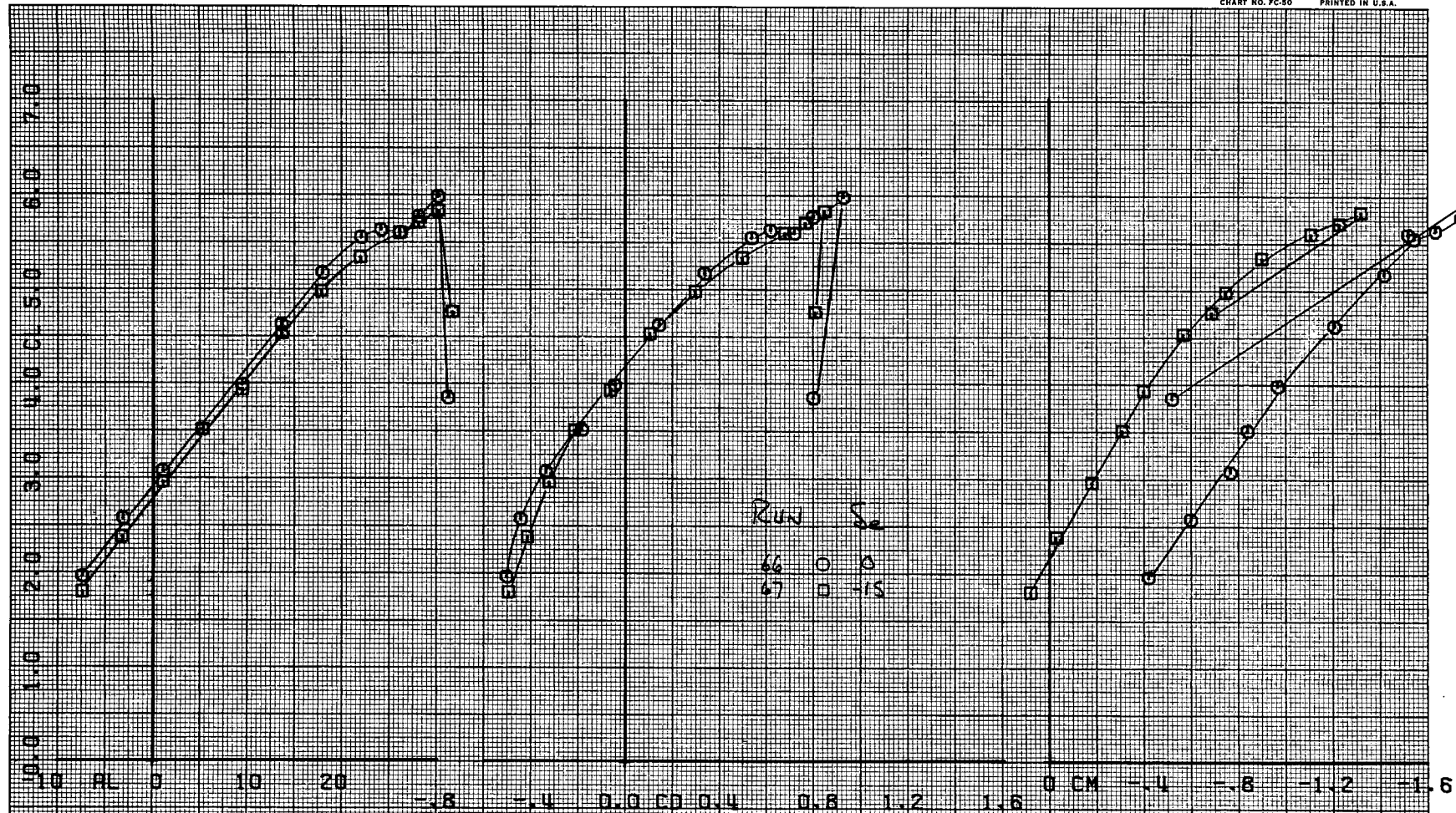


Figure 14.- Effect of elevator deflection on longitudinal aerodynamic characteristics; $\delta_f = 41.1^\circ$, $C_{J_I} = .77$, $i_t = -1^\circ$.

FIRST RUN IS 72.

COMPLÖT.

OMNIGRAPHIC.

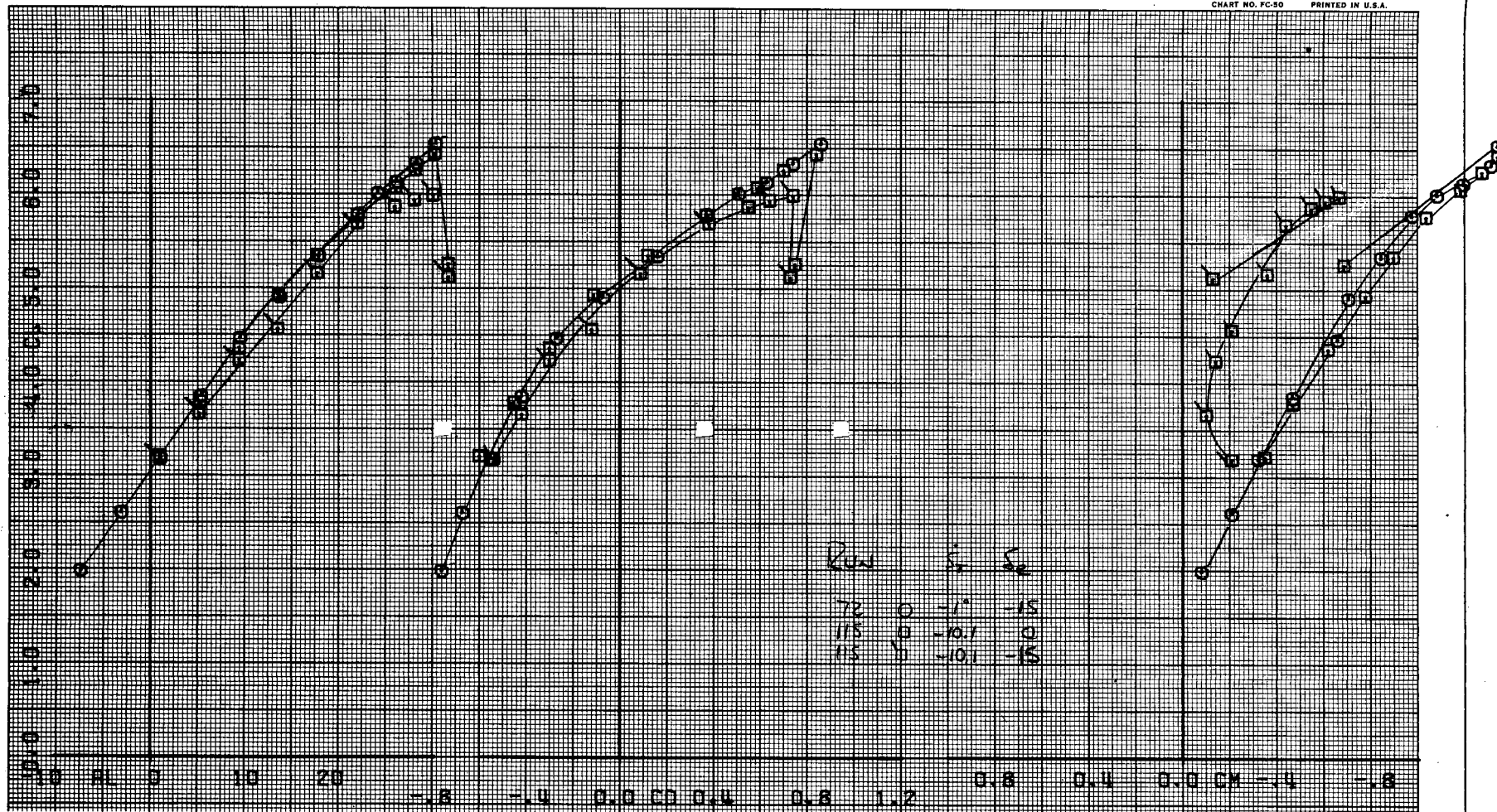
HOUSTON INSTRUMENT
DIVISION OF HARRIS CORP.
BELLAIRE, TEXAS
CHART NO. FC-50 PRINTED IN U.S.A.

Figure 15.- Effect of tail incidence on longitudinal aerodynamic characteristics; $\delta_f = 41.1$, $C_{J_I} = 1.10$.

FIRST RUN IS 6.

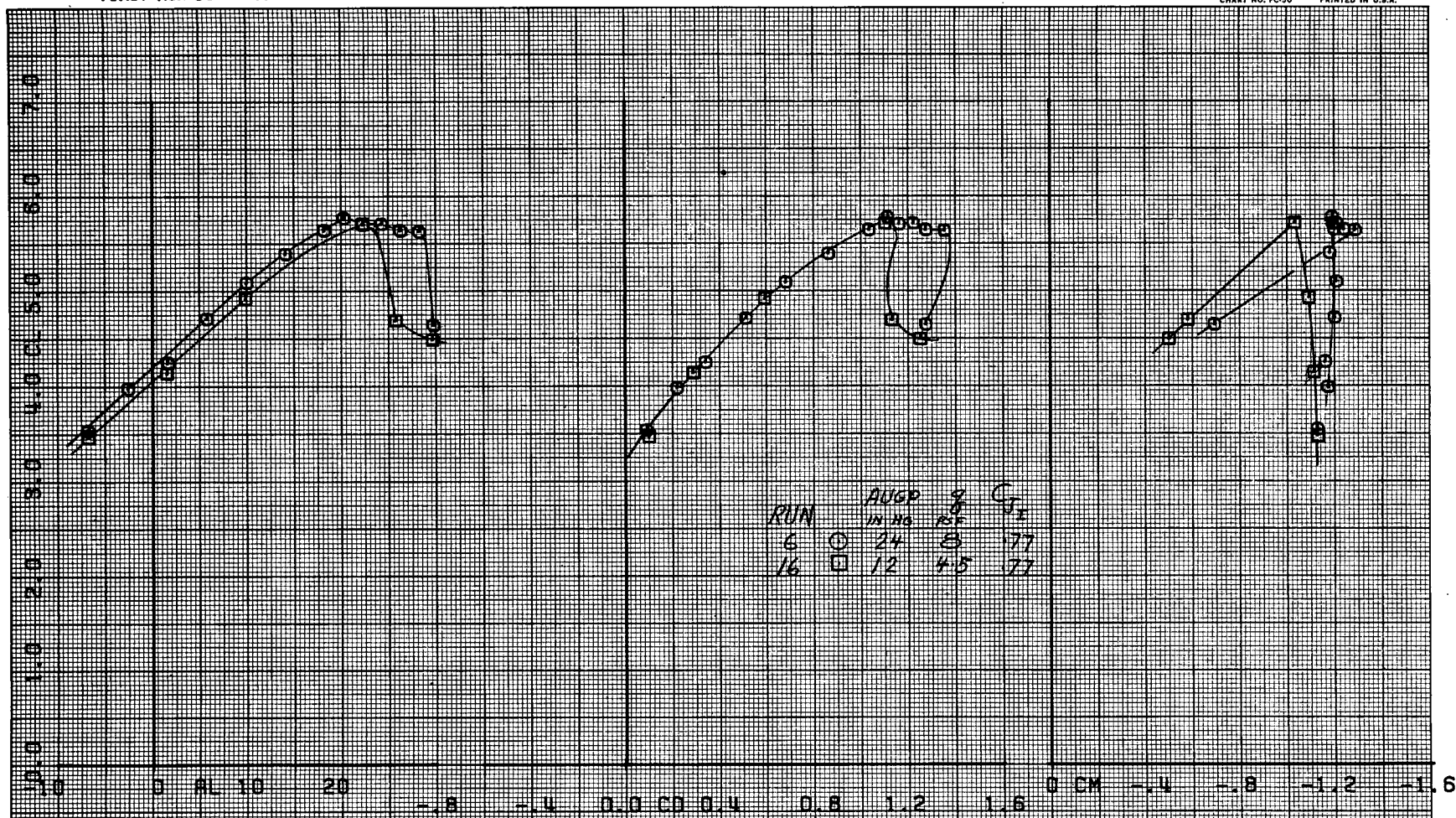
COMPLÖT_{TM}OMNIGRAPHIC_{TM}HOUSTON INSTRUMENT
DIVISION OF BUNNELL-LAMB
BELLAIRE, TEXAS
CHART NO. FC-50 PRINTED IN U.S.A.

Figure 16.- Correlation of C_{J_I} ; $\delta_f = 70.6^\circ$, $C_{J_I} = .77$.

FIRST RUN IS 167.

COMPLÖT₁₁

OMNIGRAPHIC₁₁

HOUSTON INSTRUMENT
DIVISION OF BELL & HOWELL
BELLARE, TEXAS
CHART NO. FC-50 PRINTED IN U.S.A.

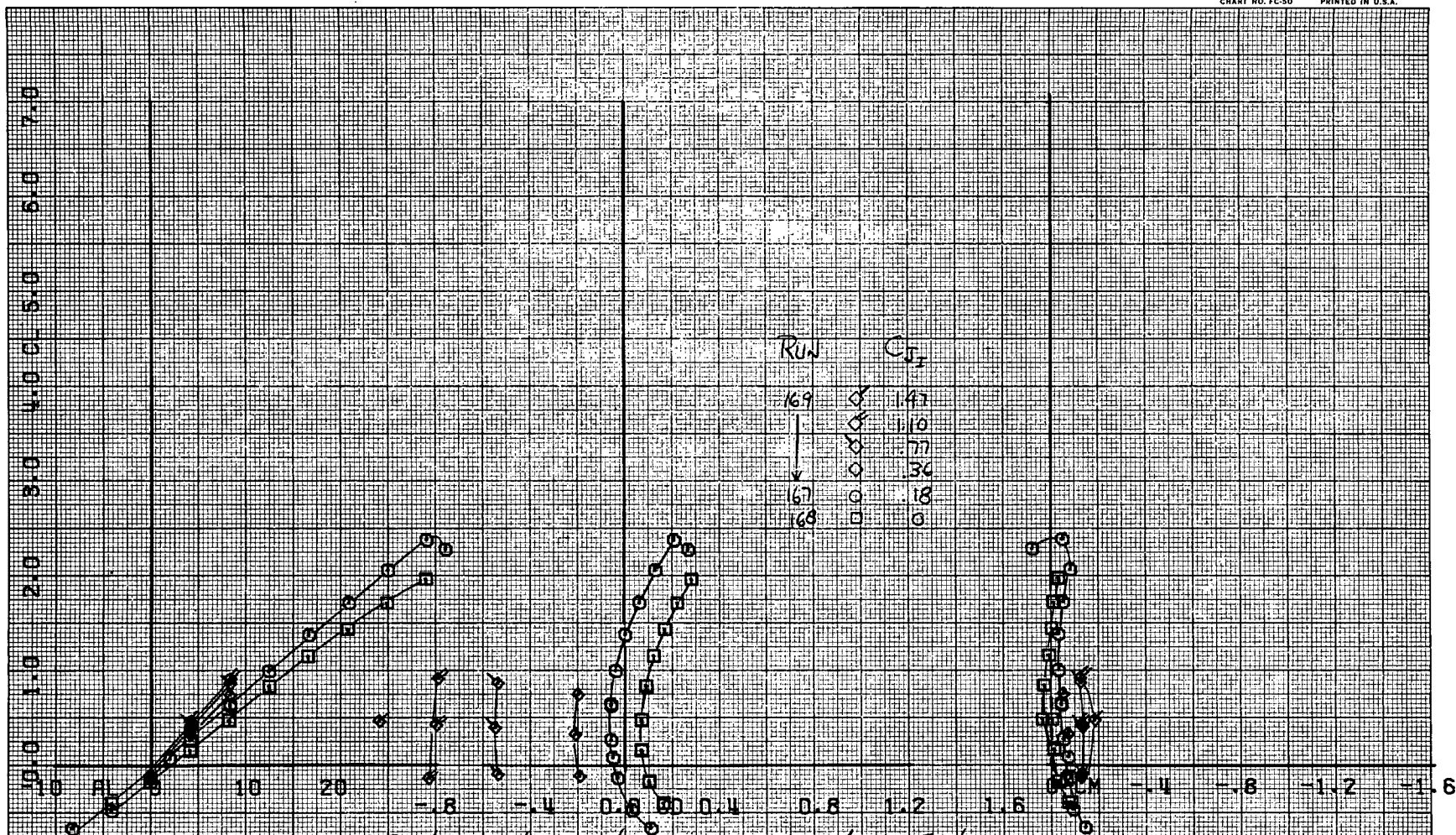


Figure 17.- Effect of C_{JT} on the longitudinal aerodynamic characteristics with horizontal tail removed; $\delta_f = 0^\circ$ and $\delta_s = 50^\circ$.

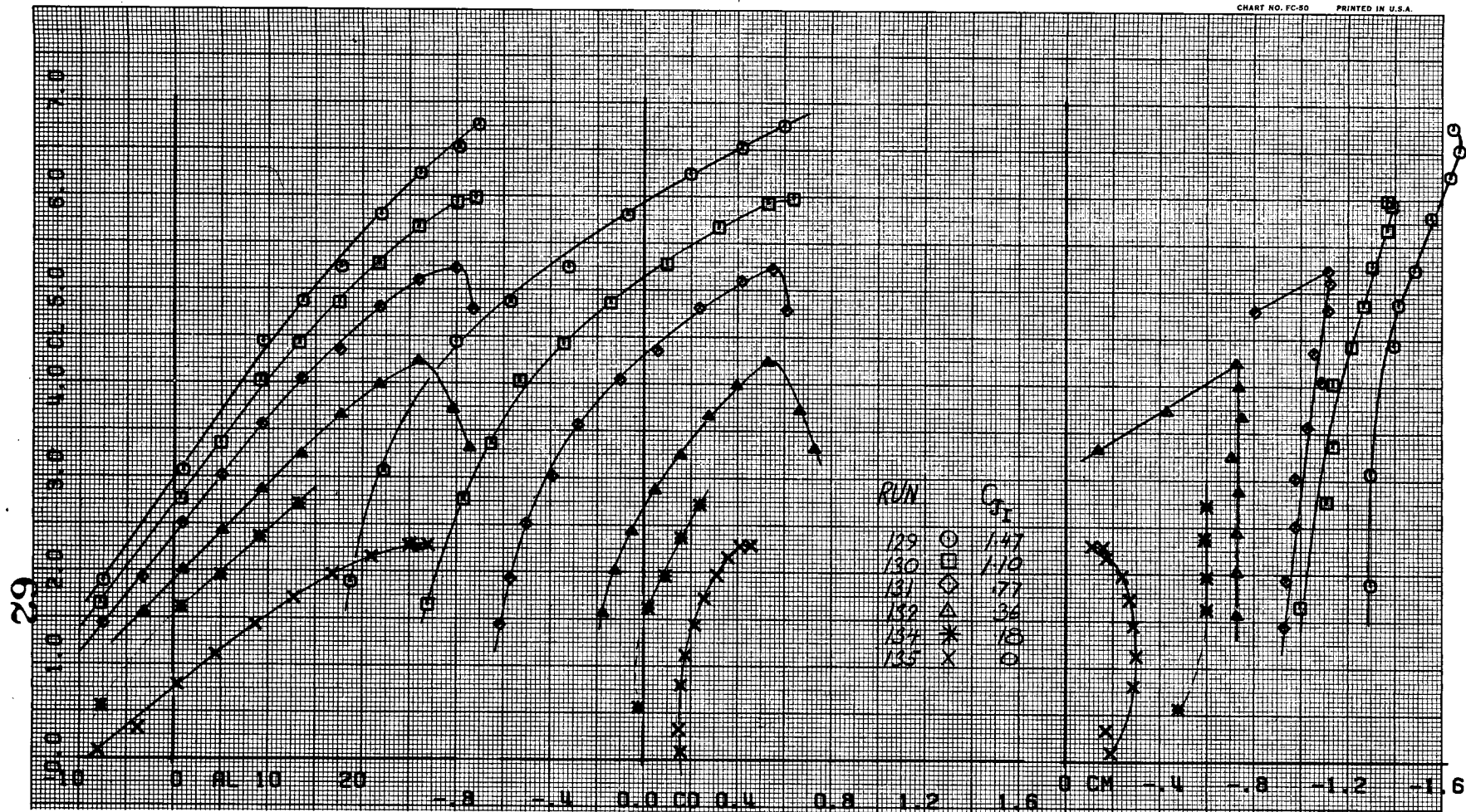


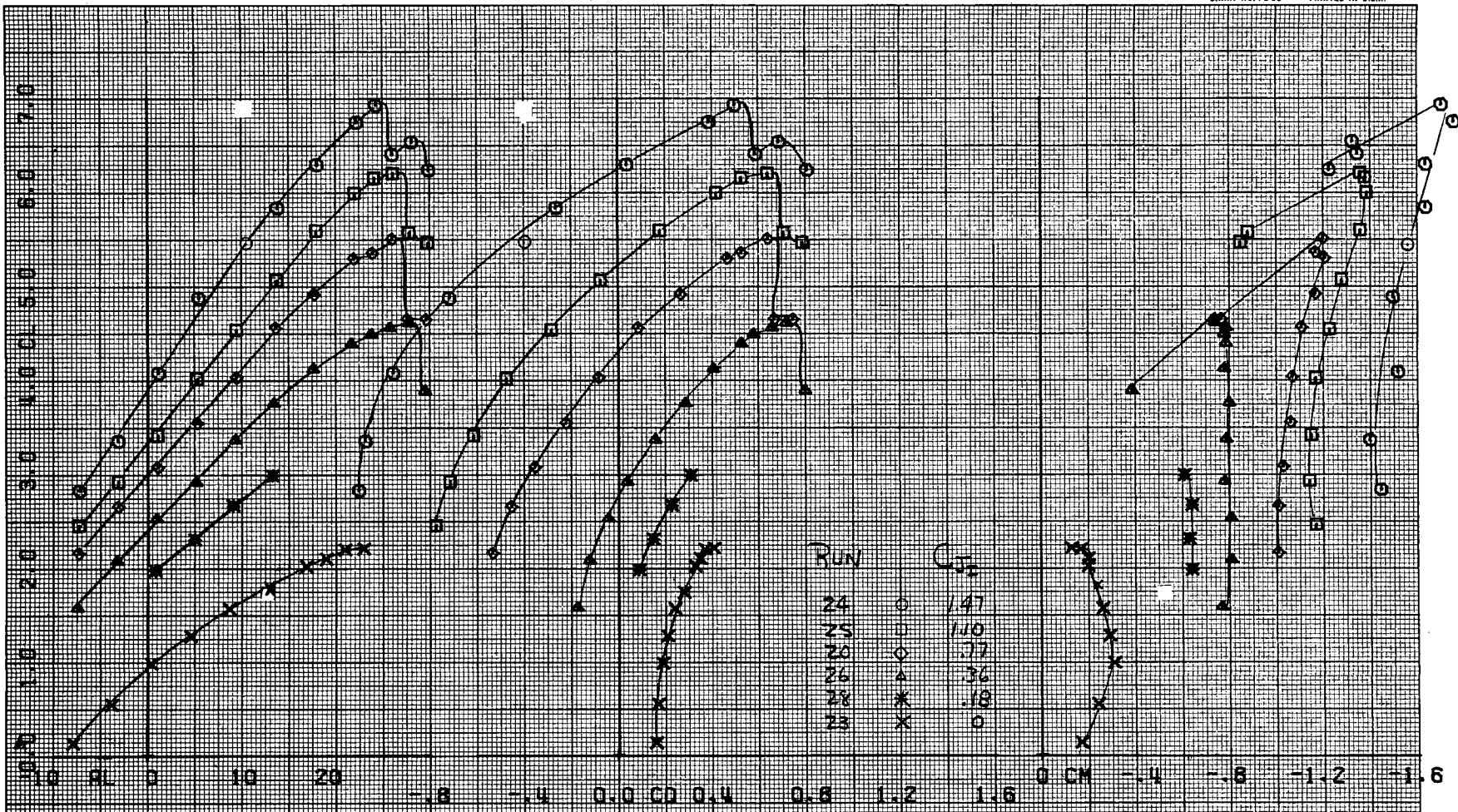
Figure 18.- Effect of C_{J_I} ON Longitudinal aerodynamic characteristics with horizontal tail removed; $\delta_f = 31.8^\circ$ and $\delta_s = 60^\circ$ (mod to stb'd).

FIRST RUN IS 24.

COMPLÖT_{TM}

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HOUSTON INSTRUMENT
DIVISION OF HARRIS-CORPORATION
BELLAIRE, TEXAS
CHART NO. FC-50 PRINTED IN U.S.A.



(a) Effect of C_{jI}

Figure 19.- Longitudinal aerodynamic characteristics with horizontal tail removed; $\delta_f = 41.1^\circ$ and $\delta_s = 60^\circ$.

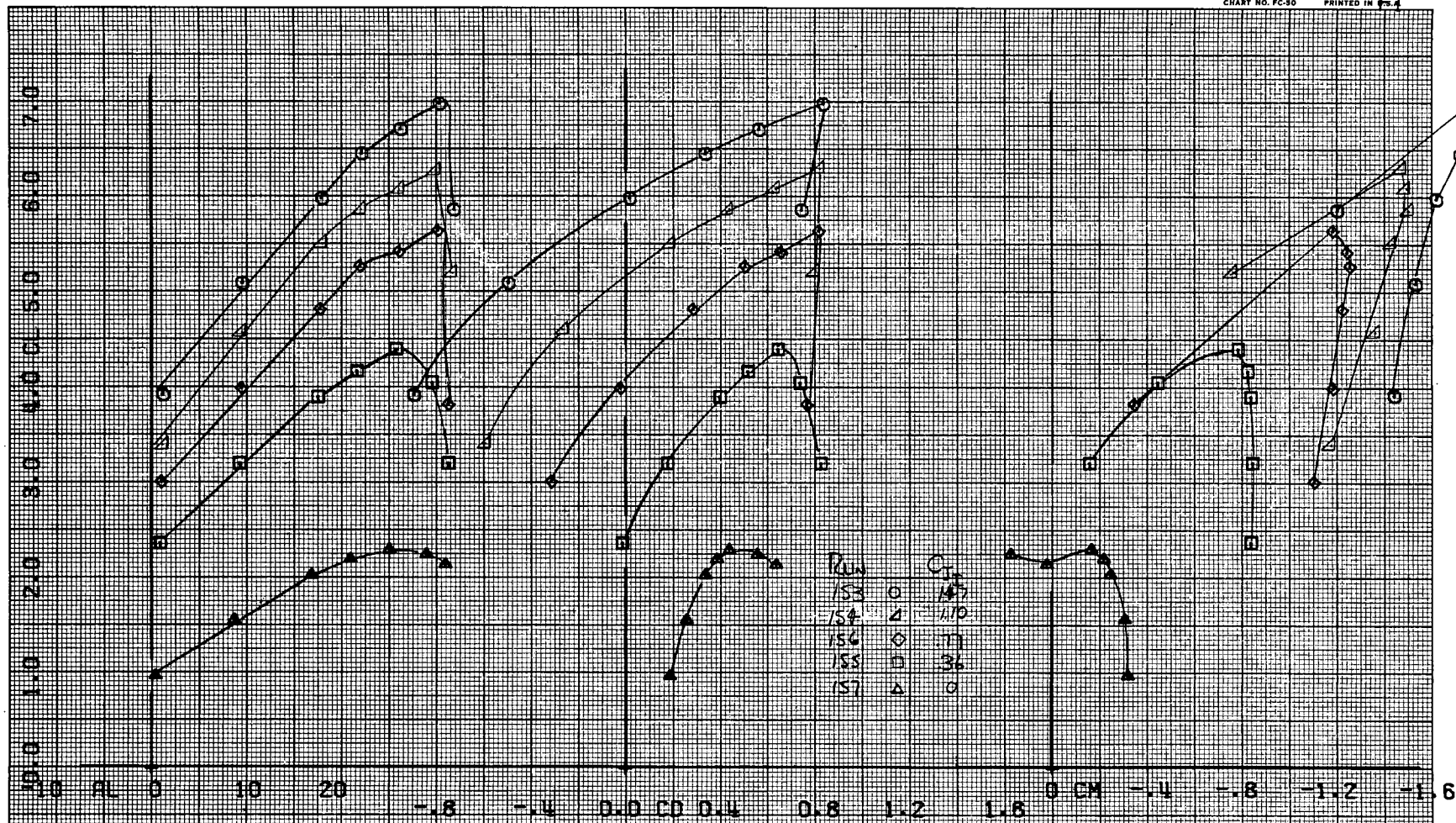
FIRST RUN IS 153.

COMPLÖT™

OMNIGRAPHIC™

HOUSTON INSTRUMENT
DIVISION OF BELL & HOWELL
BELLAIRE, TEXAS
CHART NO. FC-50 PRINTED IN U.S.A.

64



(b) Effect of C_{J_I} ; $\delta_s = 60^\circ$ (mod. to stb'd)
Figure 19.- Concluded.

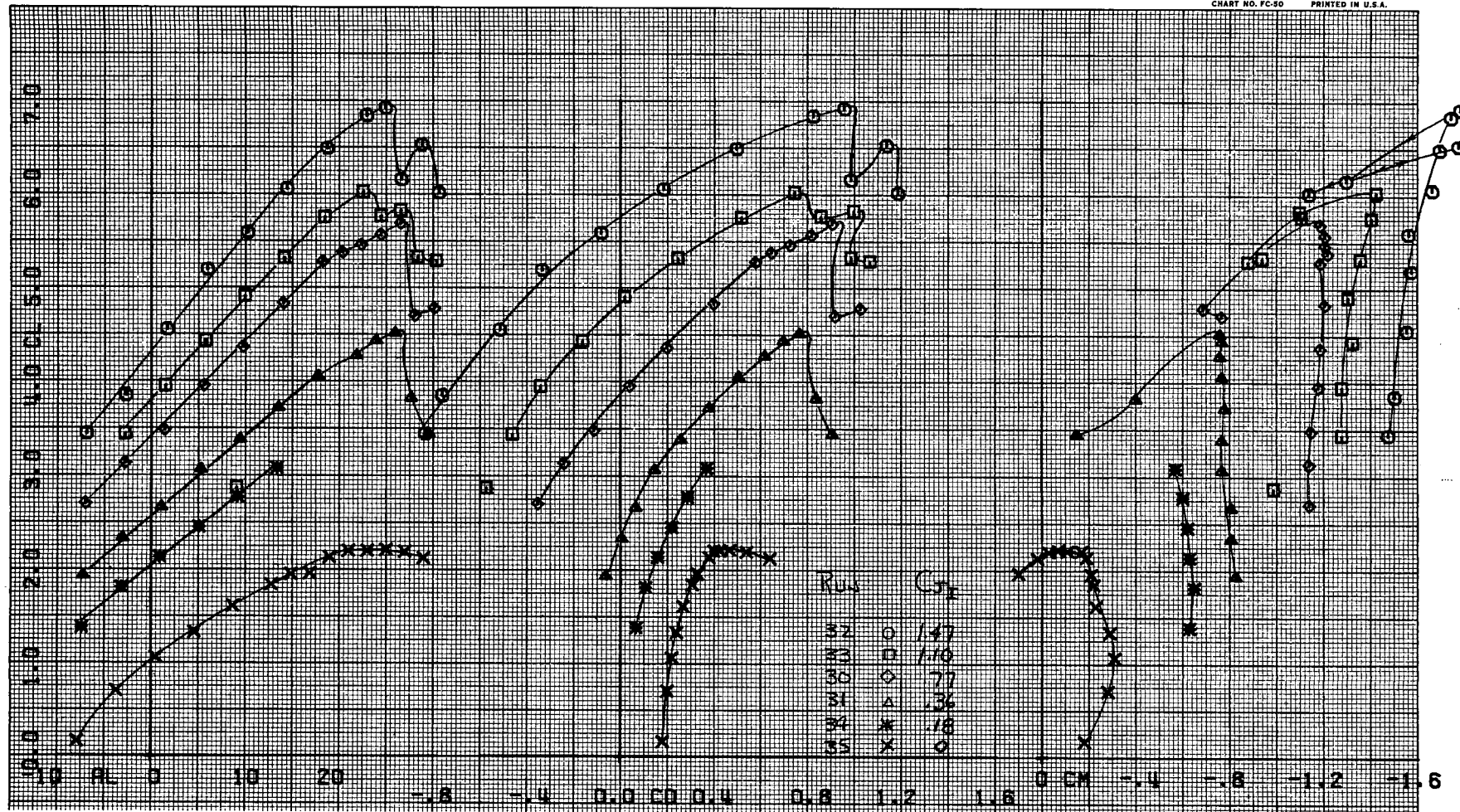


Figure 20.- Effect of C_{J_I} on the longitudinal aerodynamic characteristics with horizontal tail removed; $\delta_f = 51.1^\circ$ and $\delta_s = 60^\circ$.

99

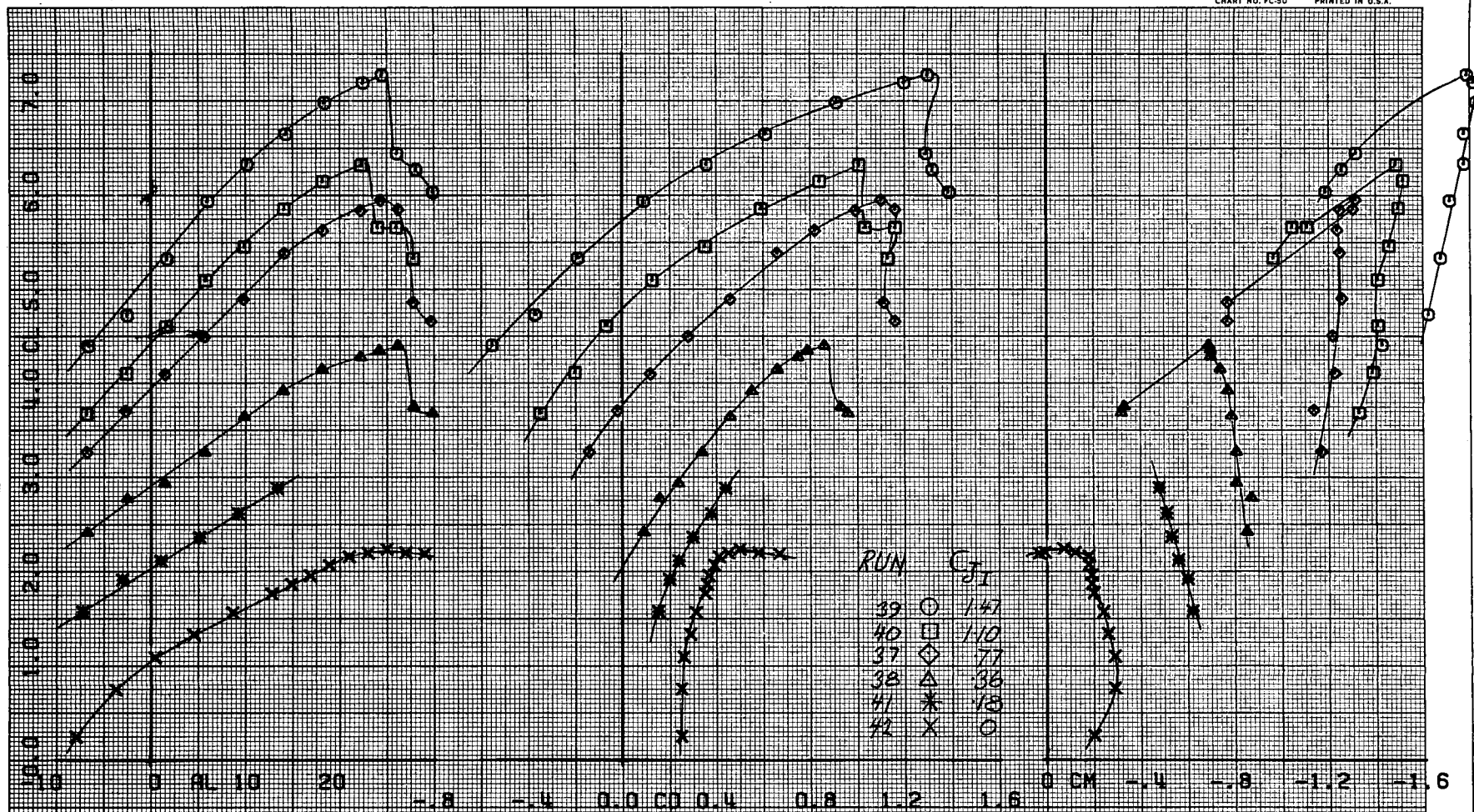
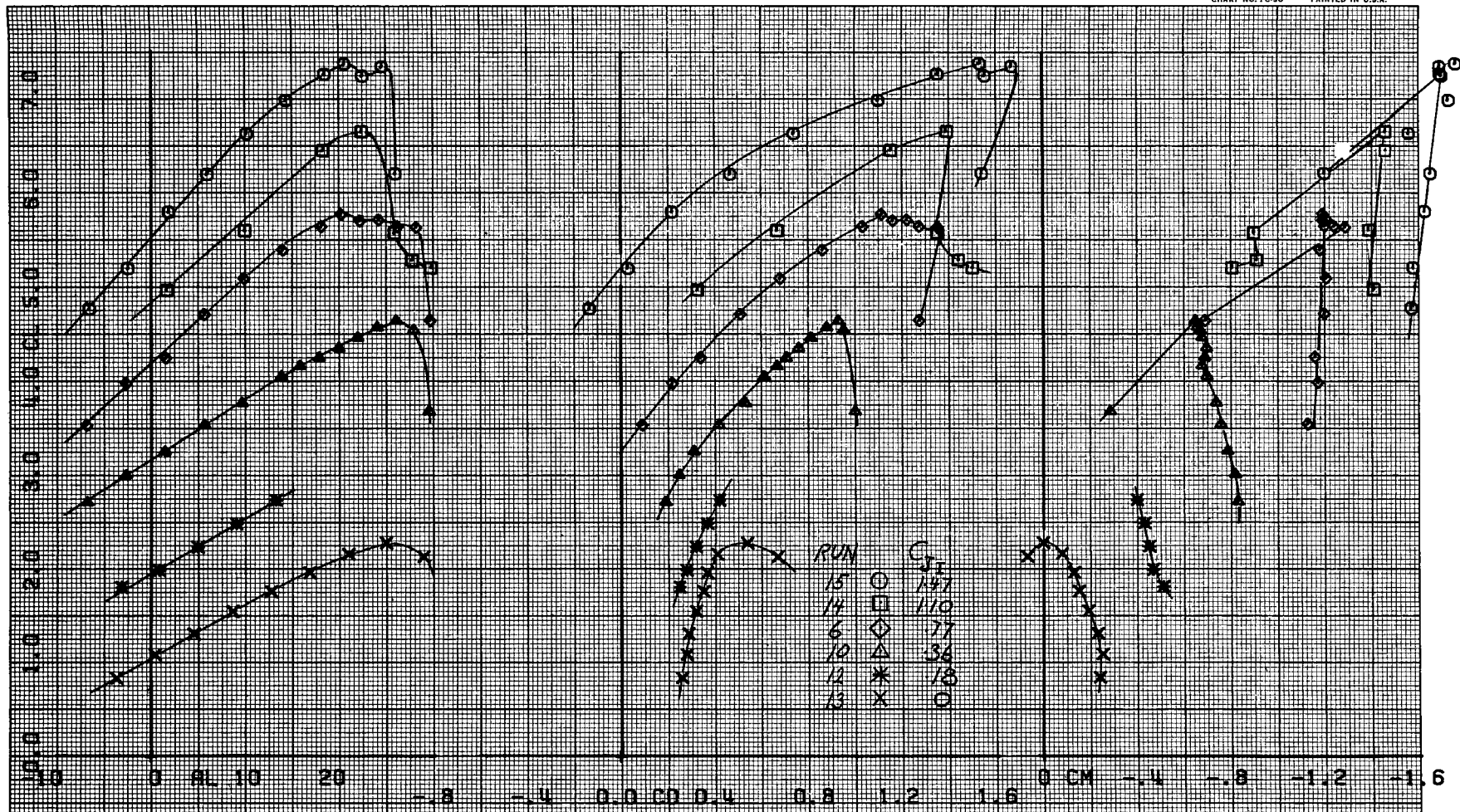


Figure 21.- Effect of C_{j_T} on the longitudinal aerodynamic characteristics with horizontal tail removed; $\delta_f = 61.2^\circ$ and $\delta_s = 60^\circ$

FIRST RUN 15 15.

COMPLÖT.

OMNIGRAPHIC.

HOUSTON INSTRUMENT
DIVISION OF BAUGHN LUBBER
BELLAIRE, TEXAS
CHART NO. FC-50 PRINTED IN U.S.A.

(a) Effect of C_{J_I}
 Figure 22.- Longitudinal aerodynamic characteristics with
 horizontal tail removed; $\delta_f = 70.6^\circ$ and $\delta_s = 60^\circ$.

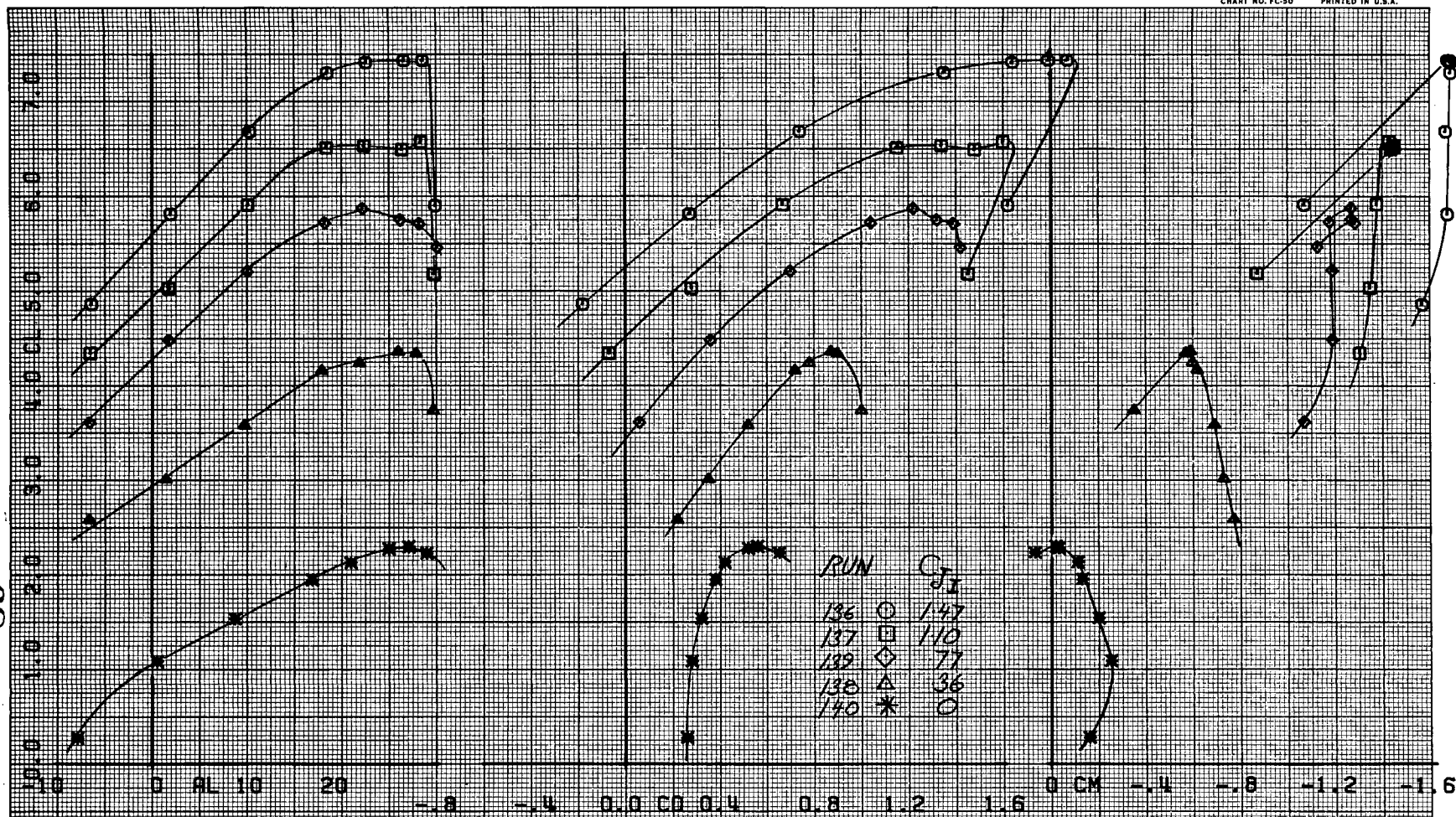
FIRST RUN IS 136.

COMPLÖT™

OMNIGRAPHIC™

VISION INSTRUMENT
DIVISION OF BELL & HOWELL CO.
BELL LAIR, TEXAS
CHART NO. FC-50 PRINTED IN U.S.A.

89



(b) Effect of C_{JI} ; $\delta_s = 60^\circ$ (mod. to stb'd)
Figure 22.- Concluded.

FIRST RUN 15 126.

COMPLÖT™

OMNIGRAPHIC™

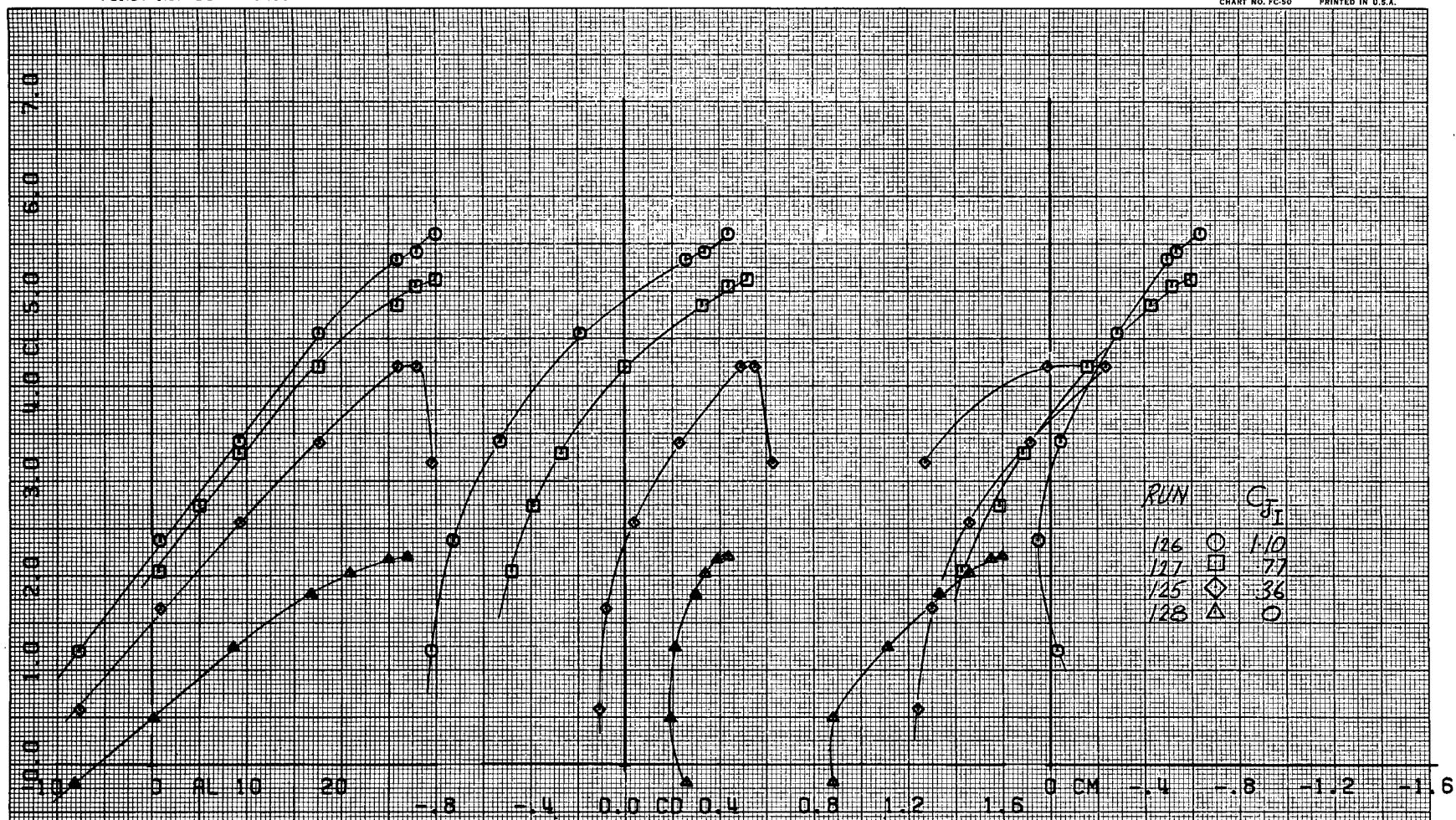
 DIVISION OF AIRCRAFT
 BELLARE, TEXAS
 CHART NO. FC-50 PRINTED IN U.S.A.


Figure 23.- Effect of C_{JI} on longitudinal aerodynamic characteristics with horizontal tail installed; $\delta_f = 31.8^\circ$, $\delta_s = 60^\circ$ (mod to stb'd), and $i_t = -10.1^\circ$.

FIRST RUN IS 69.

COMPLÖT_{TM}

OMNIGRAPHIC_{TM}

HOUSTON INSTRUMENT
DIVISION OF BALFOUR BEATTY & CO.
BELLAIRE, TEXAS
CHART NO. FC-50 PRINTED IN U.S.A.

02

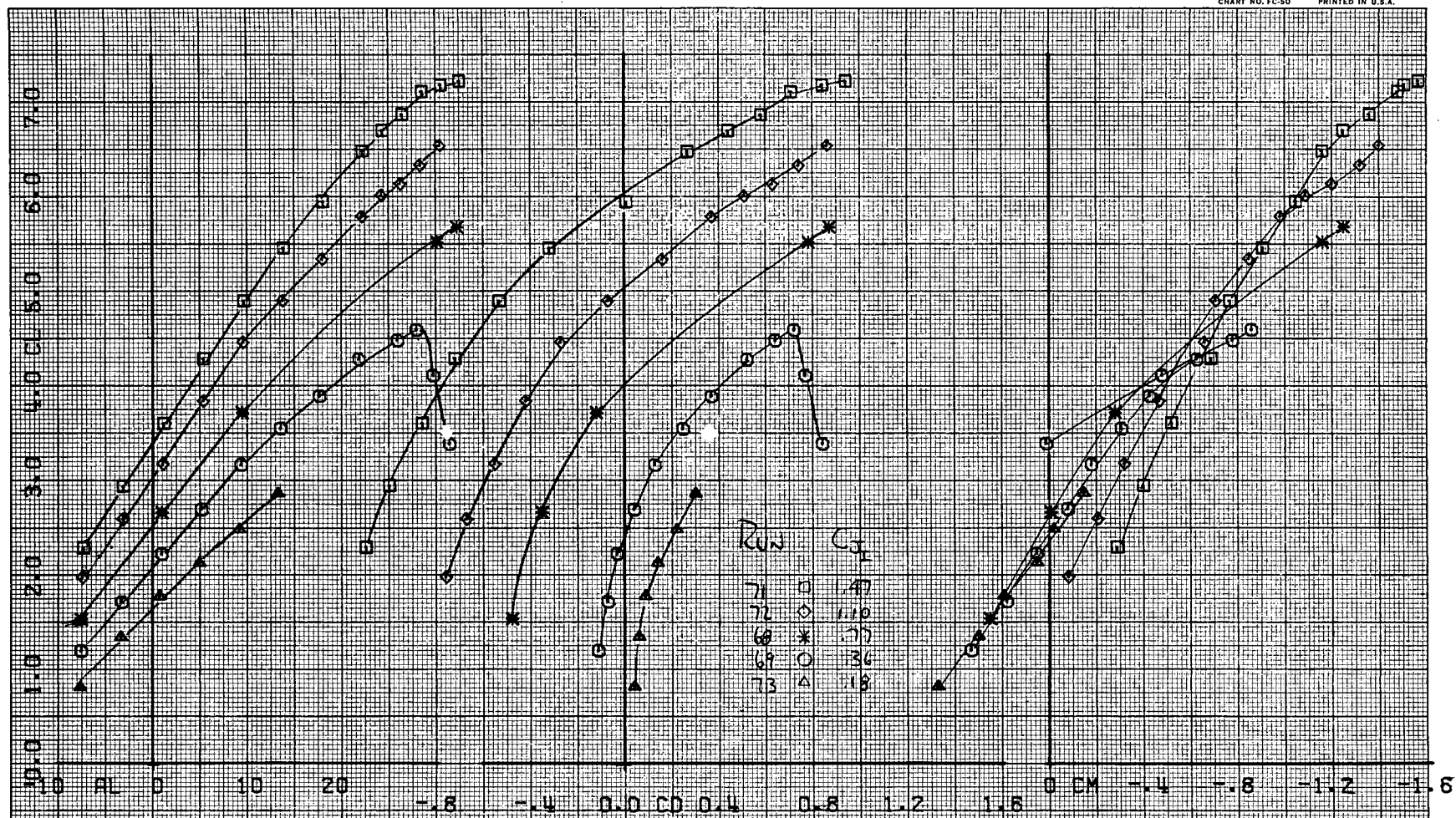


Figure 24.- Longitudinal aerodynamic characteristics with horizontal tail installed; $\delta_f = 41.1$, $\delta_s = 60^\circ$ (mod to stb'd), and $i_t = -10.1^\circ$.

FIRST RUN IS 119.

COMPLOT_{TM}

OMNIGRAPHIC_{TM}

HOUSTON INSTRUMENT
DIVISION OF BANGS & LORING
BELLAIRE, TEXAS
CHART NO. FC-50 PRINTED IN U.S.A.

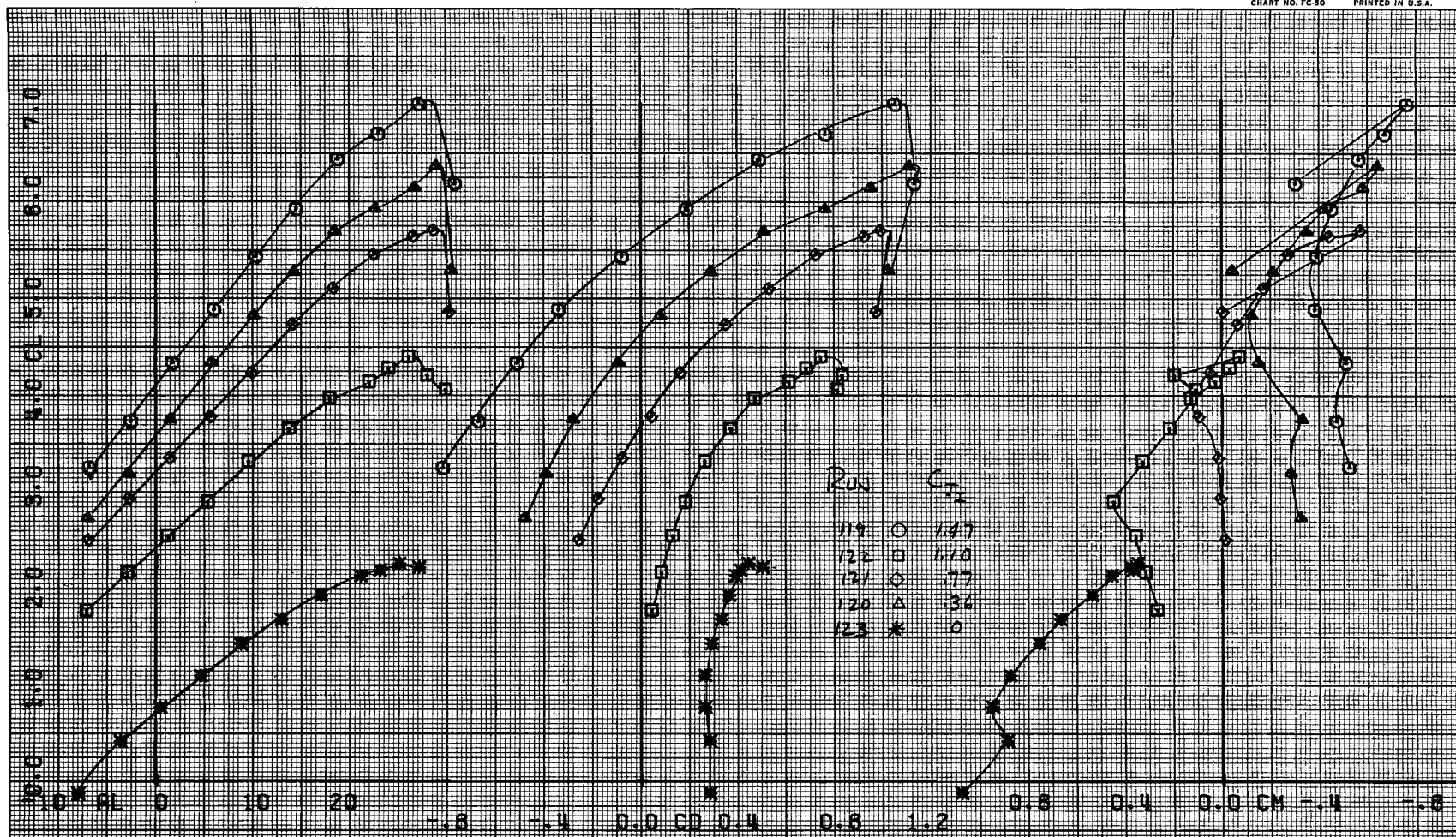
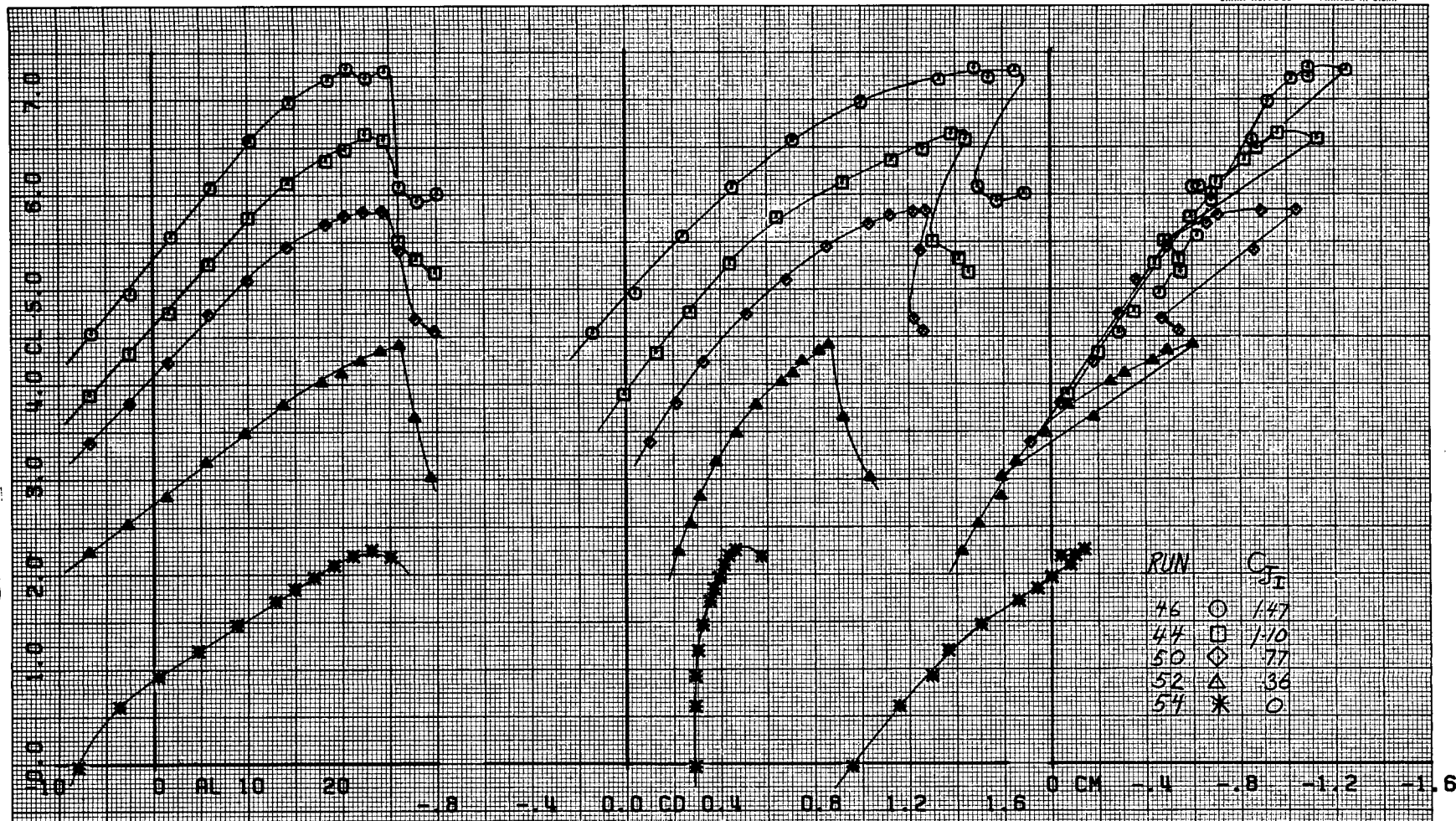


Figure 25.- Effect of C_{jT} on longitudinal aerodynamic characteristics with horizontal tail installed; $\delta_f = 51.1^\circ$, $\delta_s = 60^\circ$ (mod to stb'd), and $i_t = -10.1^\circ$.

22



(a) Effect of C_{JI} ; $\delta_e = -15^\circ$

Figure 26.- Longitudinal aerodynamic characteristics with horizontal tail installed; $\delta_f = 70.6^\circ$, $= 60^\circ$, and $i_f = -1^\circ$.

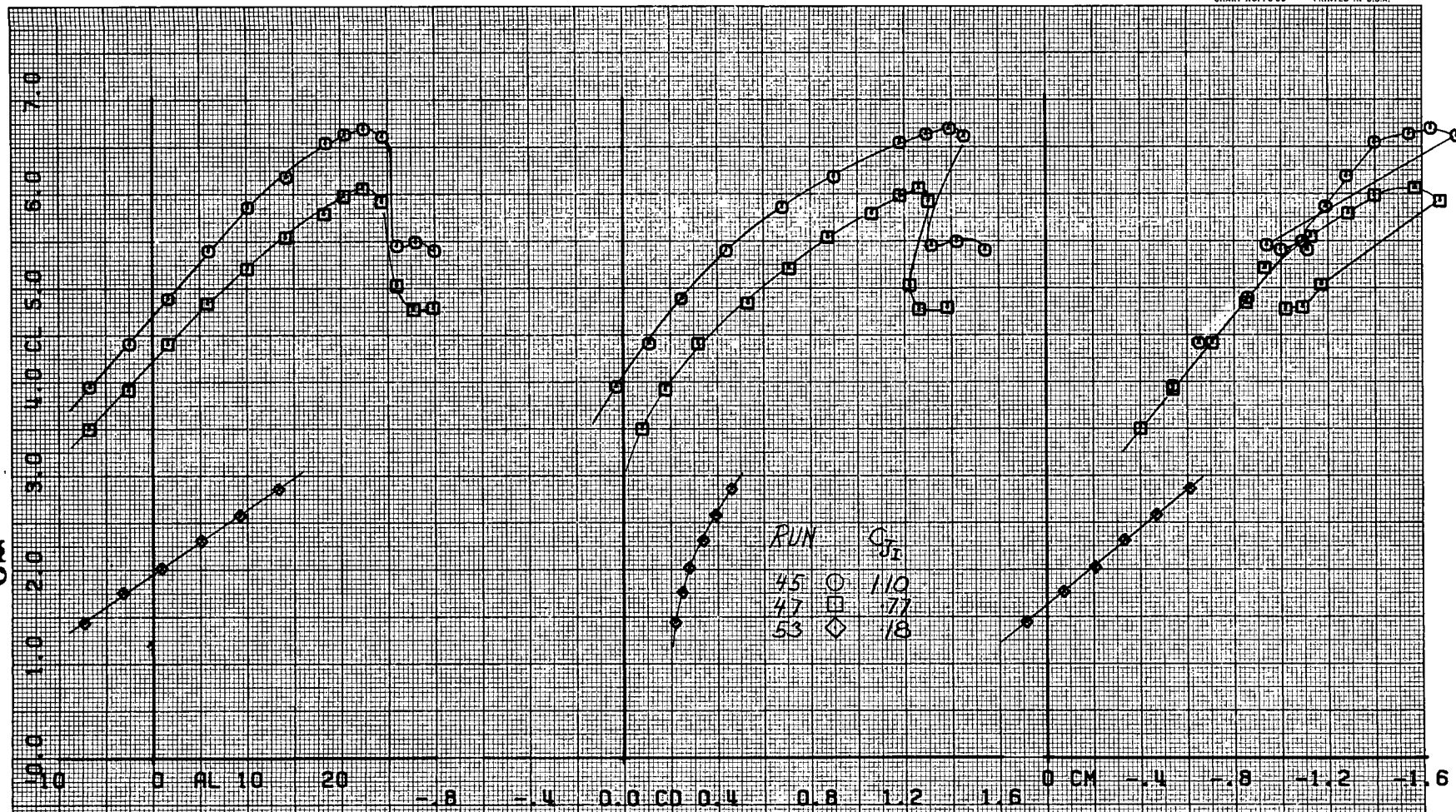
FIRST RUN IS 45.

COMPLÖT_{TM}

OMNIGRAPHIC_{TM}

HOUSLON INSTRUMENT
DIVISION OF BUNDELL CORP.
BELLAIRE, TEXAS
CHART NO. FC-50 PRINTED IN U.S.A.

73



(b) Effect of C_{JI} ; $\delta_e = 0^\circ$

Figure 26.- Continued.

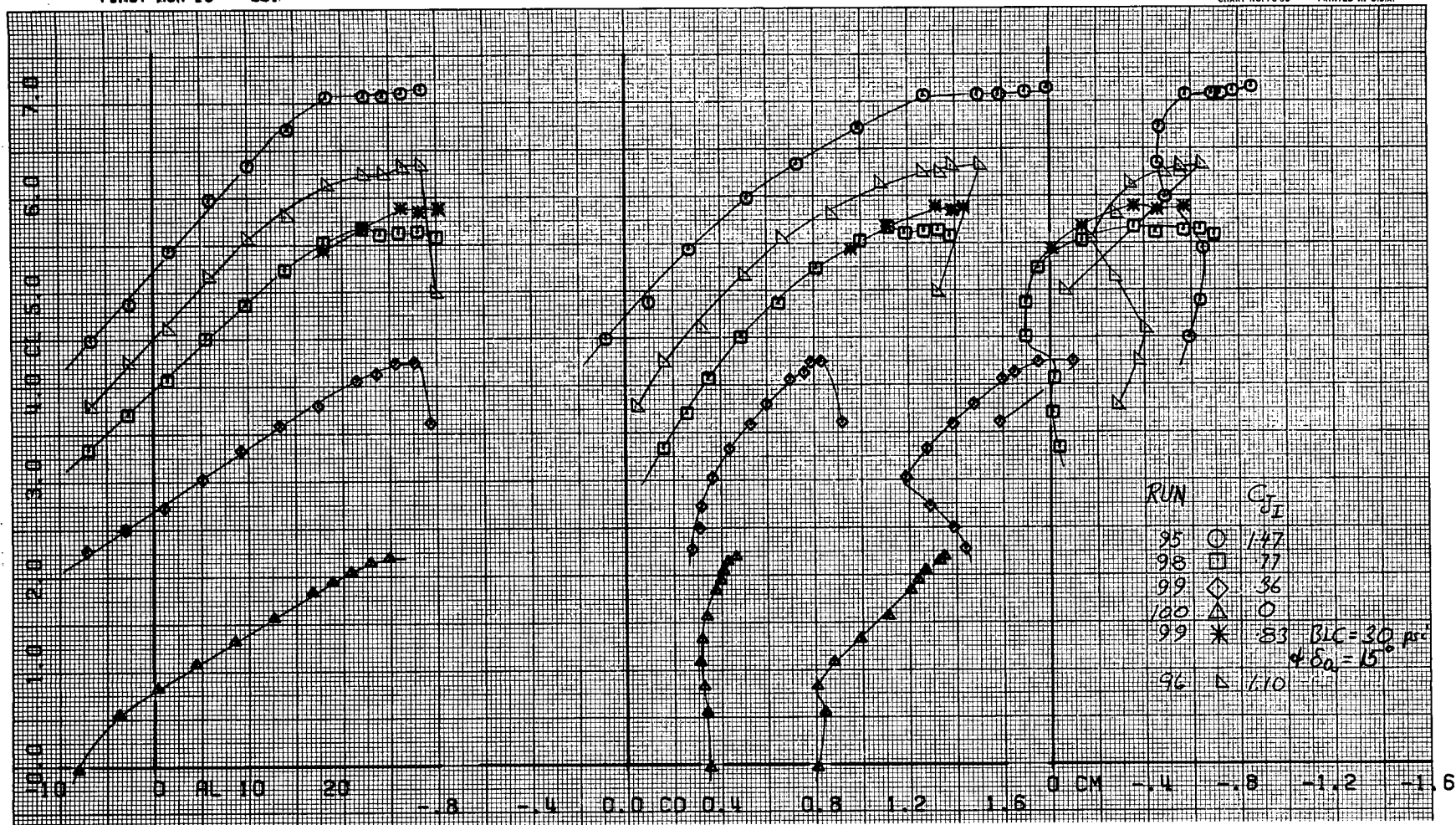
FIRST RUN IS 95.

COMPLÖT.

OMNIGRAPHIC.

HOUSTON INSTRUMENT
DIVISION OF BUSHNELL & LORAIN
BELLAIRE, TEXAS
CHART NO. FC-50 PRINTED IN U.S.A.

74



(c) Effect of C_{JI} ; $\delta_s = 60^\circ$ (mod. to stb'd), and $i_t = -10.1^\circ$

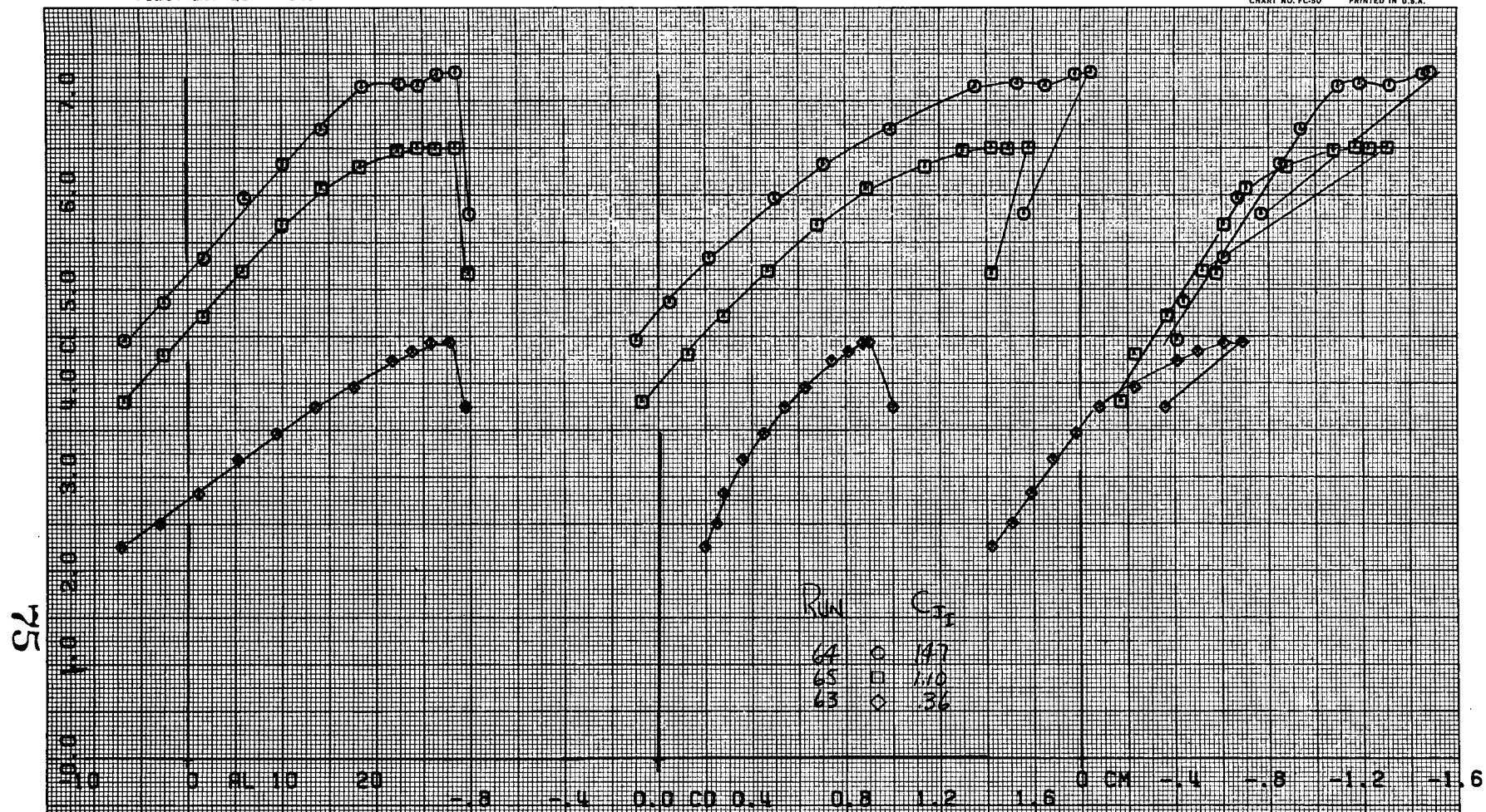
Figure 26- Continued.

F1A5T RUN 15 64.

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(d) Effect of C_{J_I} ; $\delta_s = 60^\circ$ (mod. to stb'd), $i_t = -1^\circ$

Figure 26.- Concluded.

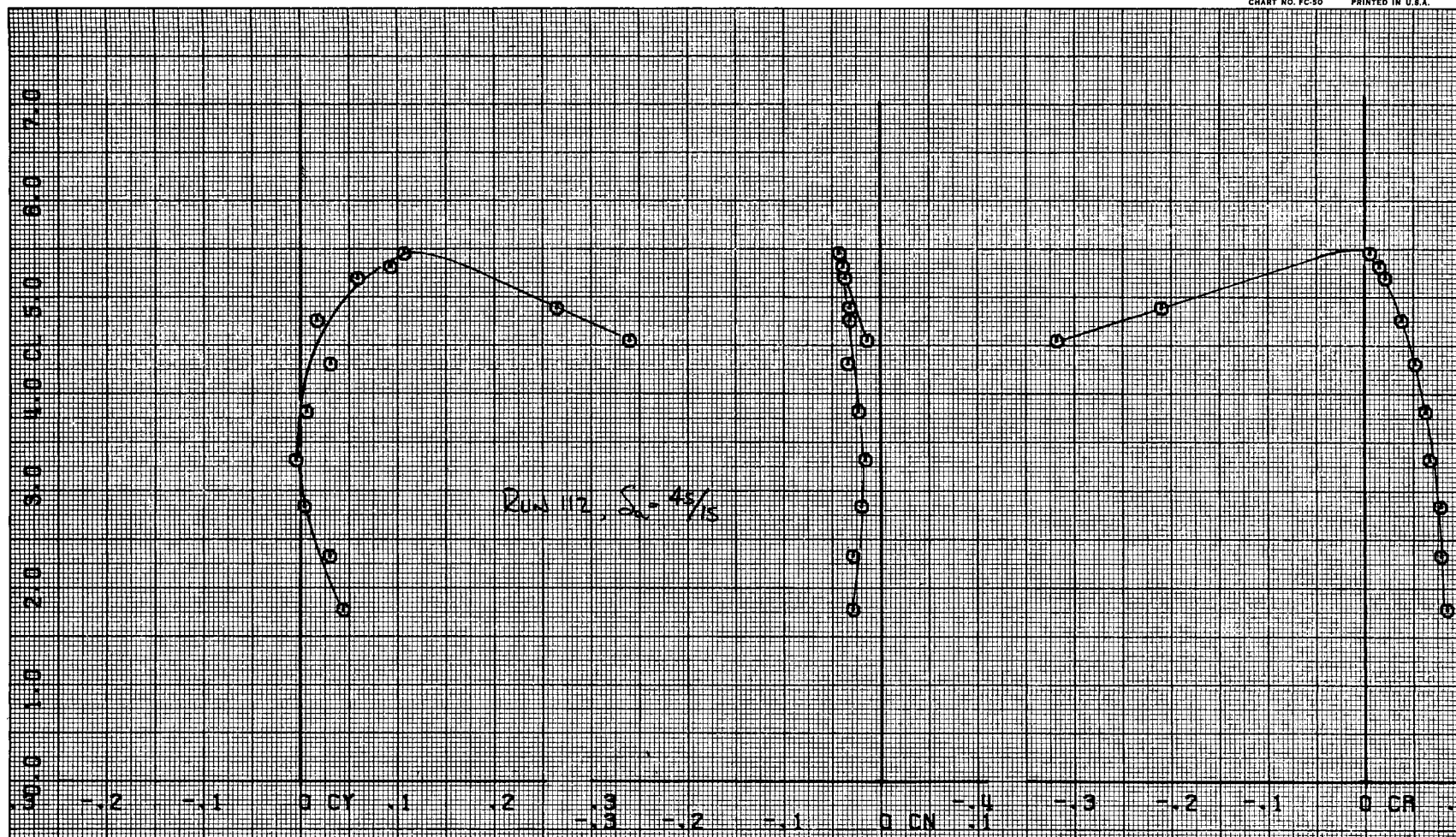
FIRST RUN IS 112.

COMPLOT_{TM}

OMNIGRAPHIC_{TM}

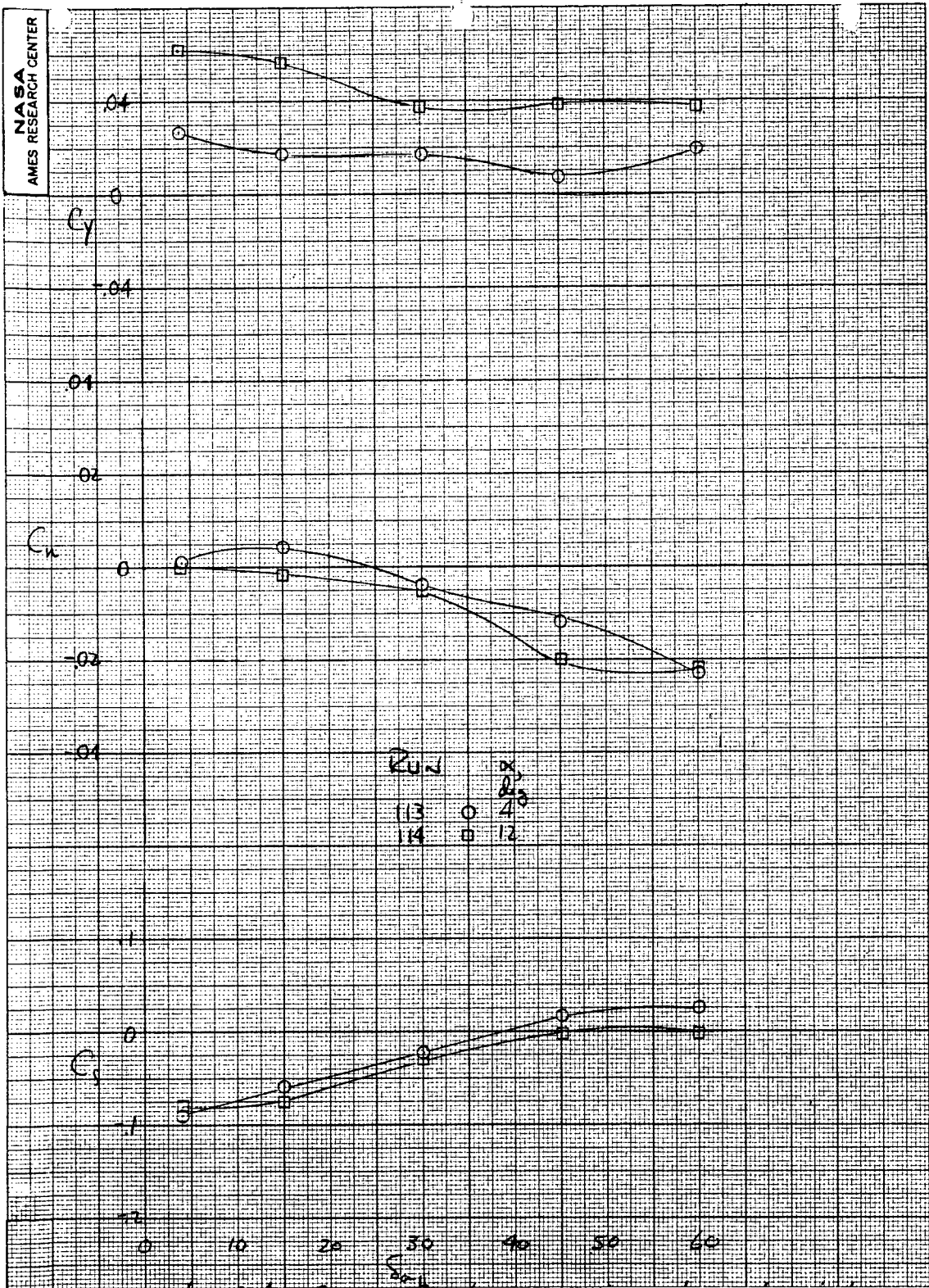
HOUSTON INSTRUMENT
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BELLAIRE, TEXAS

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(a) $\delta_a = 45/15^\circ$

Figure 27.- Effect of differential aileron deflection on lateral-direction characteristics; $\delta_f = 41.1^\circ$.



(b) $\delta_a = n/30^\circ$

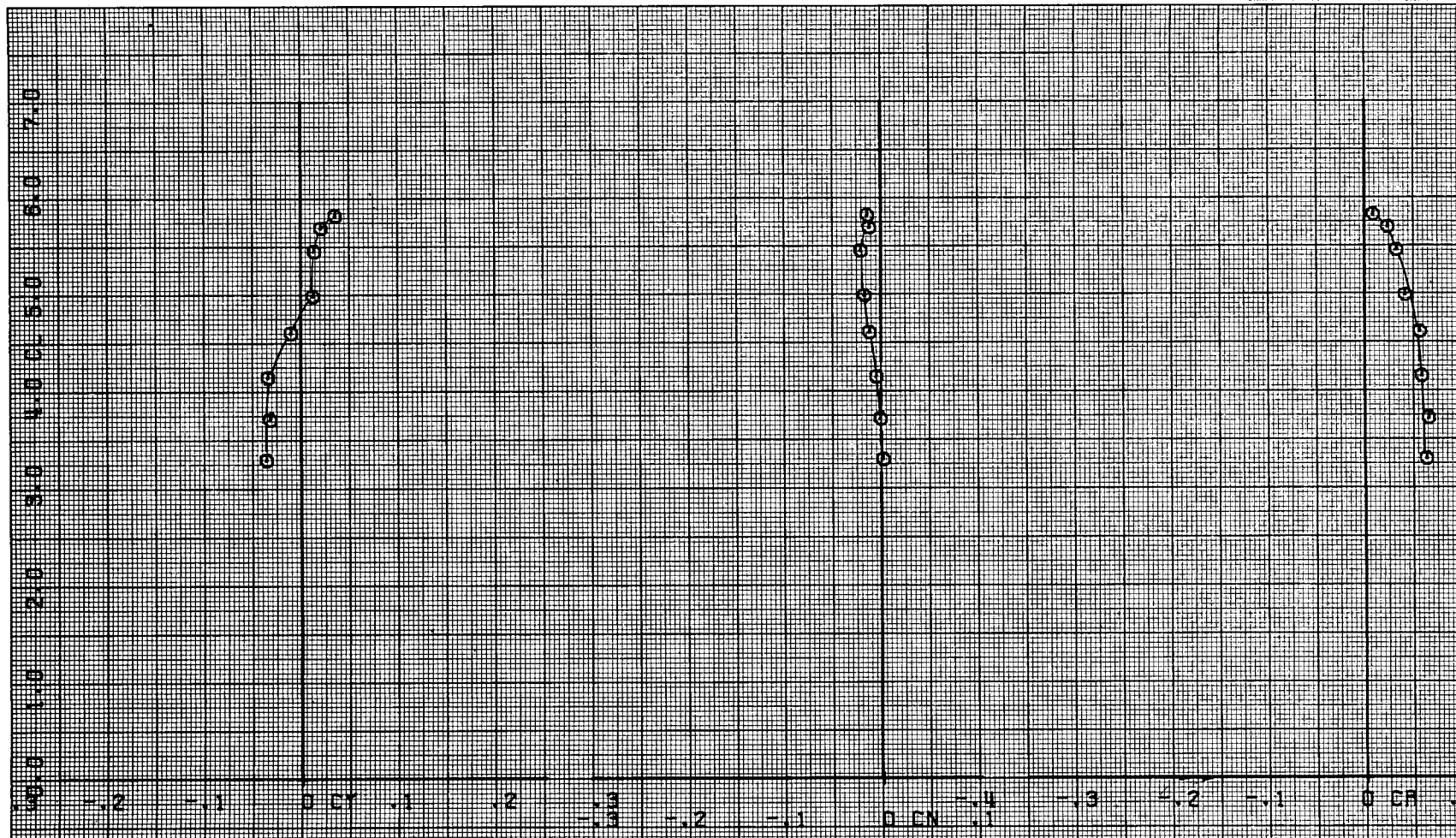
Figure 27.- Concluded.

FIRST RUN IS 82.

COMPLØT,

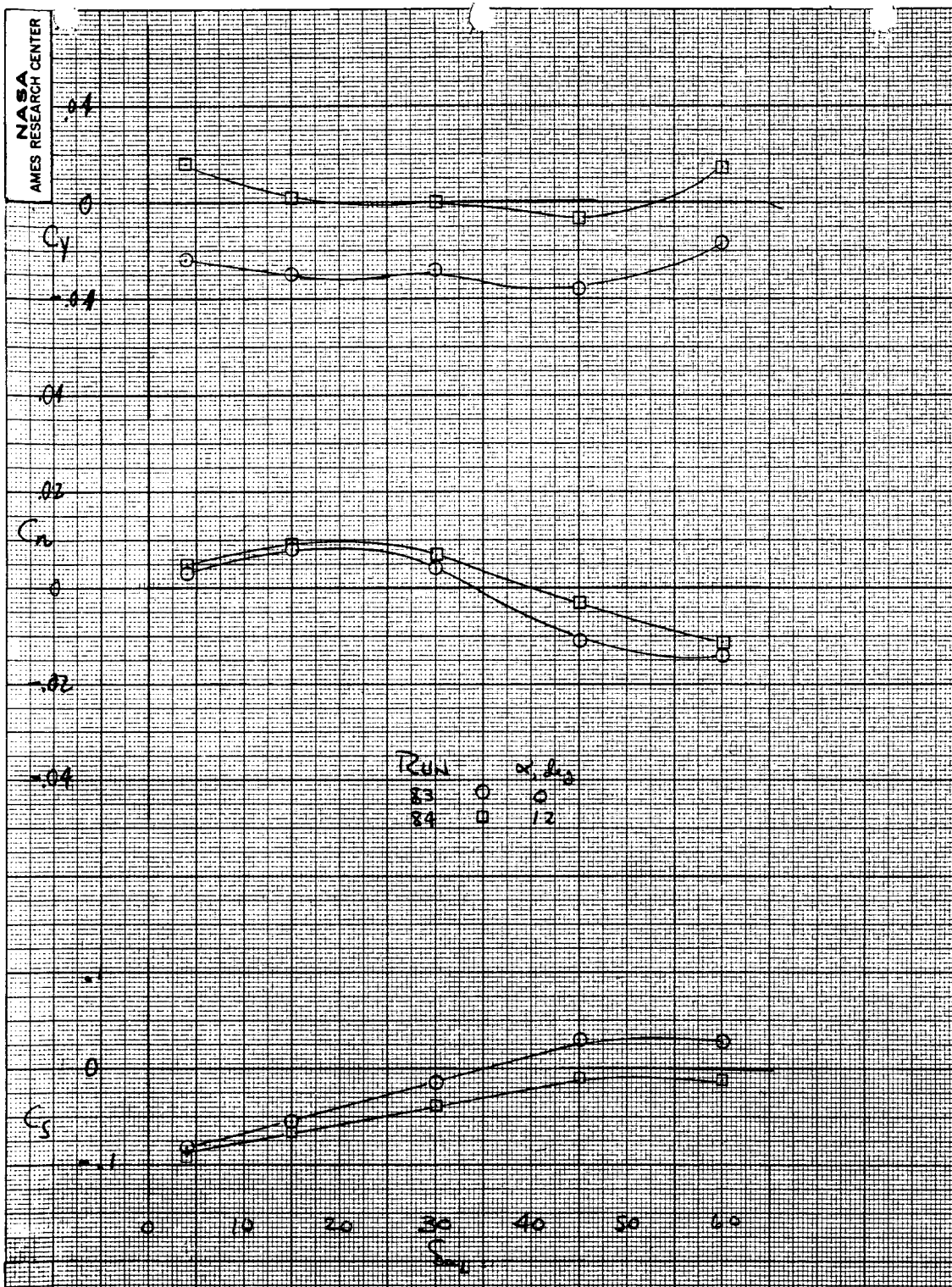
OMNIGRAPHIC,

HOUSTON INSTRUMENT
DIVISION OF BANGOR LAMSON
BELL LAIR, TEXAS
CHART NO. FC-50 PRINTED IN U.S.A.

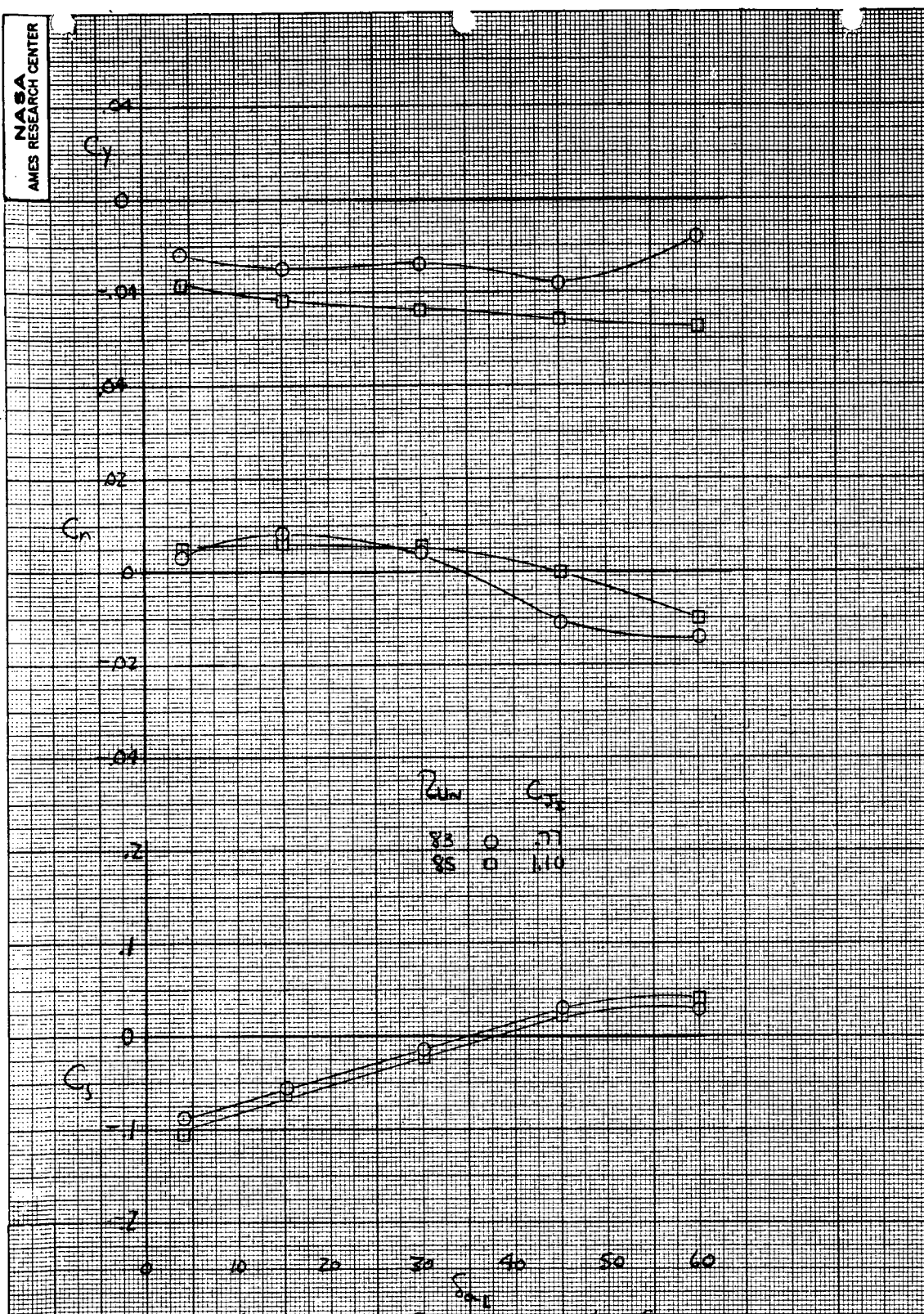


(a) $\delta_a = 45/15^\circ$

Figure 28.- Effect of differential aileron deflection lateral-directional characteristics; $\delta_f = 70.6^\circ$.



(b) Effect of variable port aileron; $\delta_a = n/30$, $\alpha = 0^\circ$ and 12°
Figure 28.- Continued.



(c) Effect of variable port aileron; $\delta_a = n/30^\circ$ and $C_{J_I} = .77$ and 1.10
Figure 28.- Concluded.

FIRST RUN 15 59.

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DIVISION OF HANCOCK & CO.
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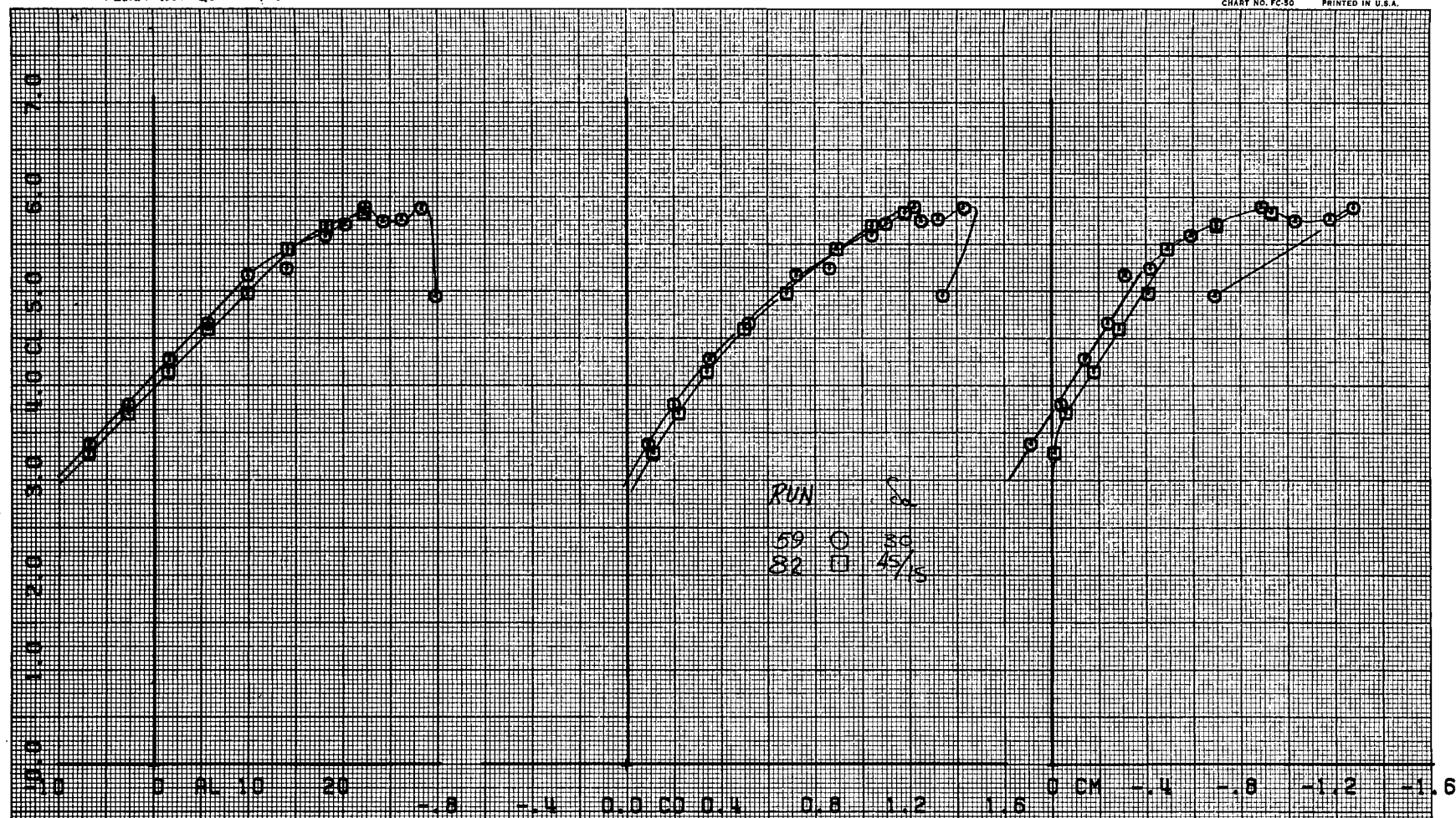


Figure 29.- Effect of differential aileron deflection on longitudinal aerodynamic characteristics with horizontal tail installed; $\delta_f = 70.6$, $\delta_s = 60^\circ$ (mod to stb'd) $\delta_a = 30^\circ$ and $45/15^\circ$ and $i_t = -1^\circ$

FIRST RUN IS 67.

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DIVISION OF BARRINGER
BELLARE, TEXAS
CHART NO. FC-50 PRINTED IN U.S.A.

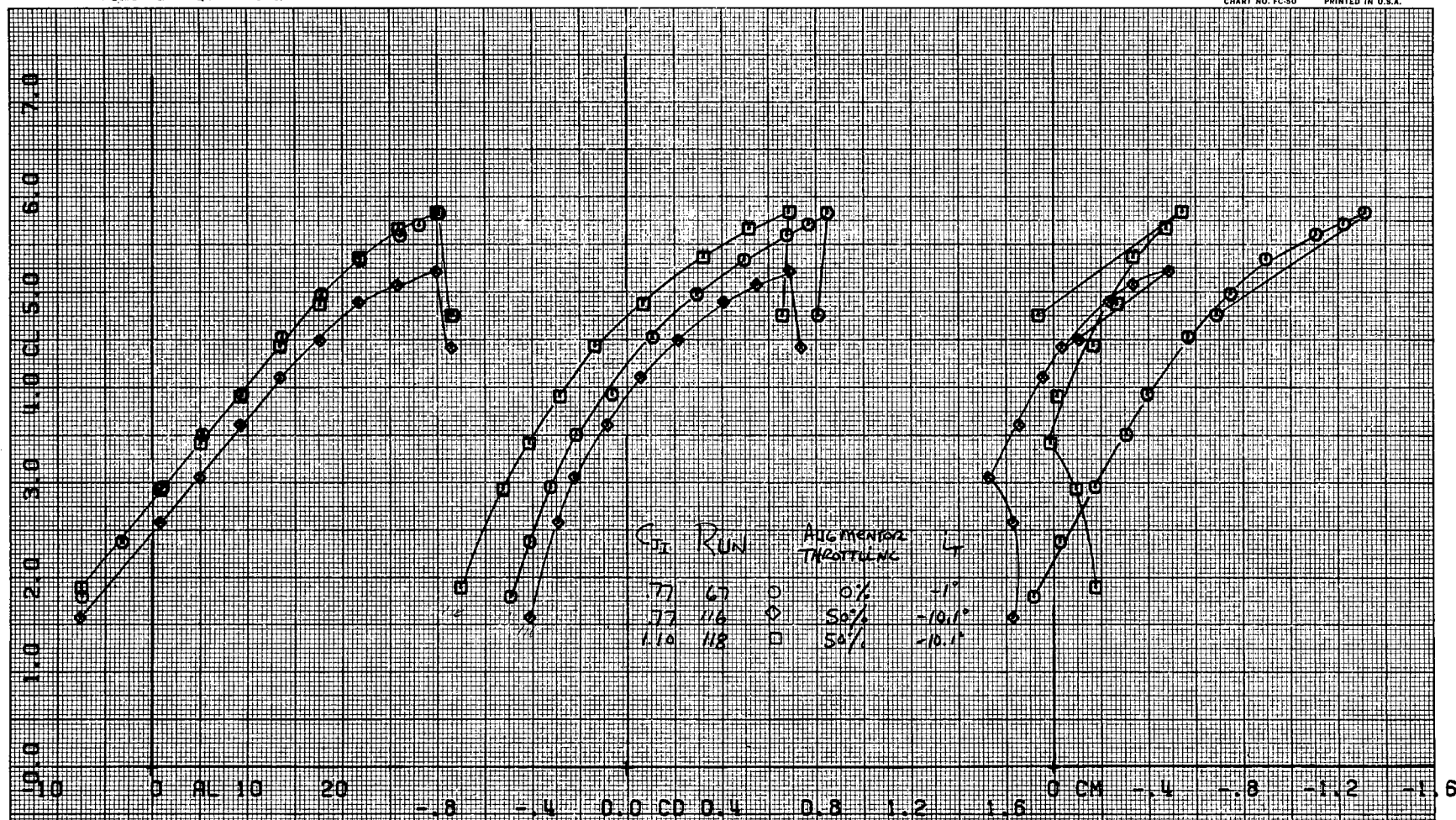


Figure 30.- Effect of augmentor throttling on longitudinal aerodynamic characteristics with horizontal tail installed; $\delta_f = 41.1$, $\delta_s = 60^\circ$ (mod to stb'd).

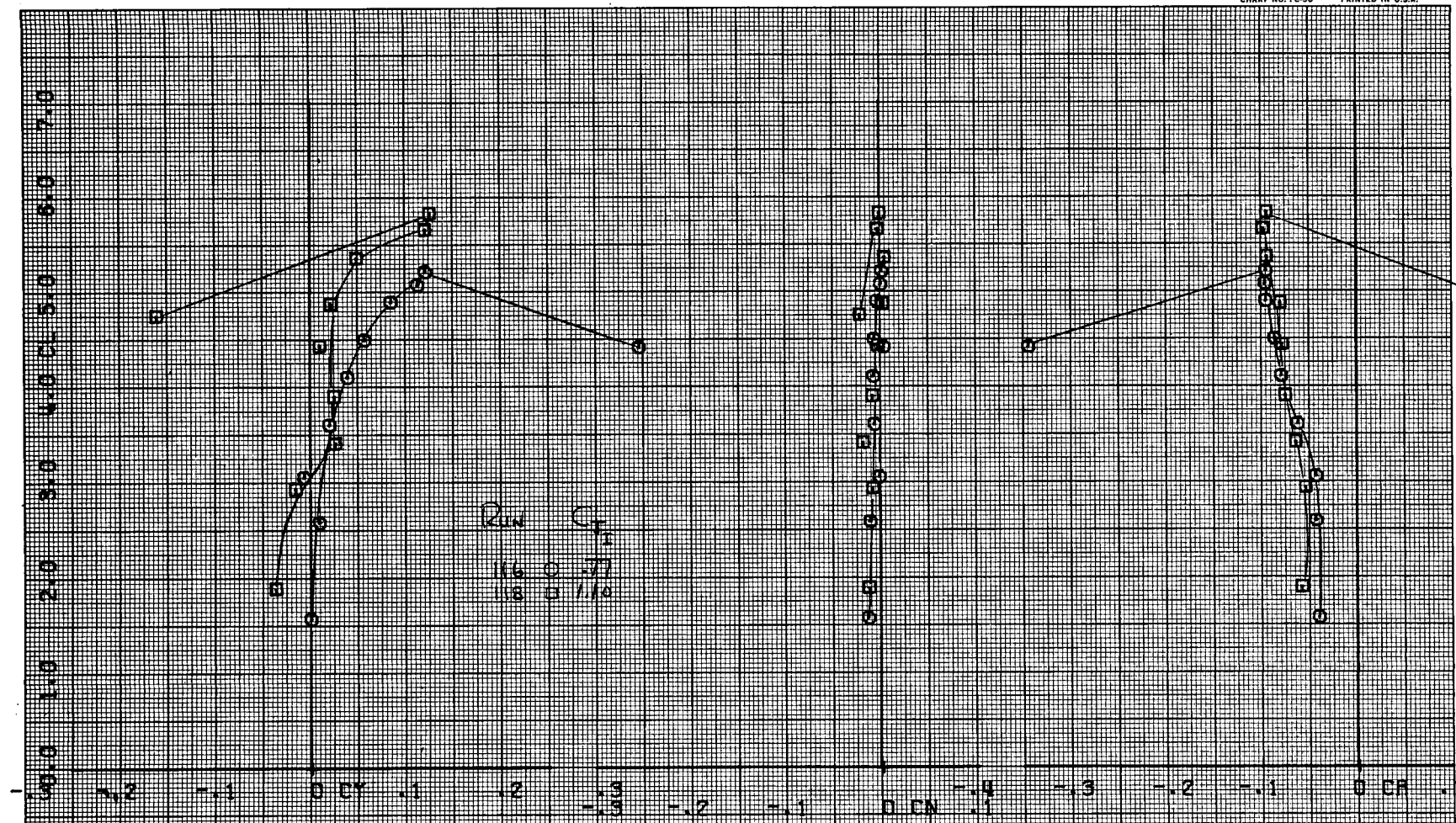
FIRST RUN IS 116.

COMPLÖT™

OMNIGRAPHIC™

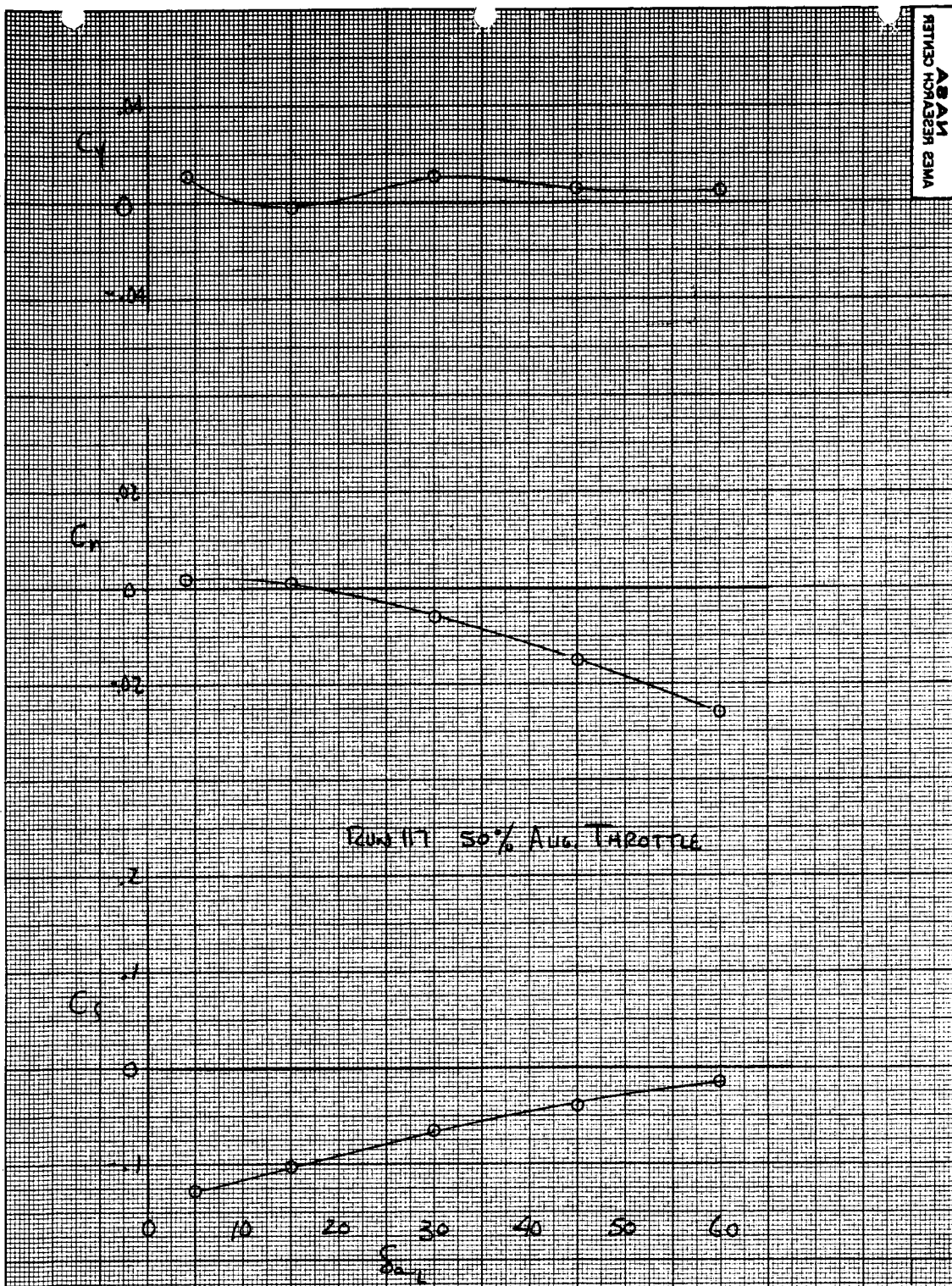
HOUSTON INSTRUMENT
DIVISION OF BORG-WARNER
BELLAIRE, TEXAS

CHART NO. FC-50 PRINTED IN U.S.A.



(a) $C_{J_I} = .77$ and 1.10

Figure 31.- Effect of augmentor throttling on lateral-directional characteristics; $\delta_f = 41.1$ and $\Delta d = 50\%$.



(b) $\delta_a = n/30^\circ$

Figure 31.- Concluded.

FIRST RUN 13 59.

COMPLÖT.

OMNIGRAPHIC.

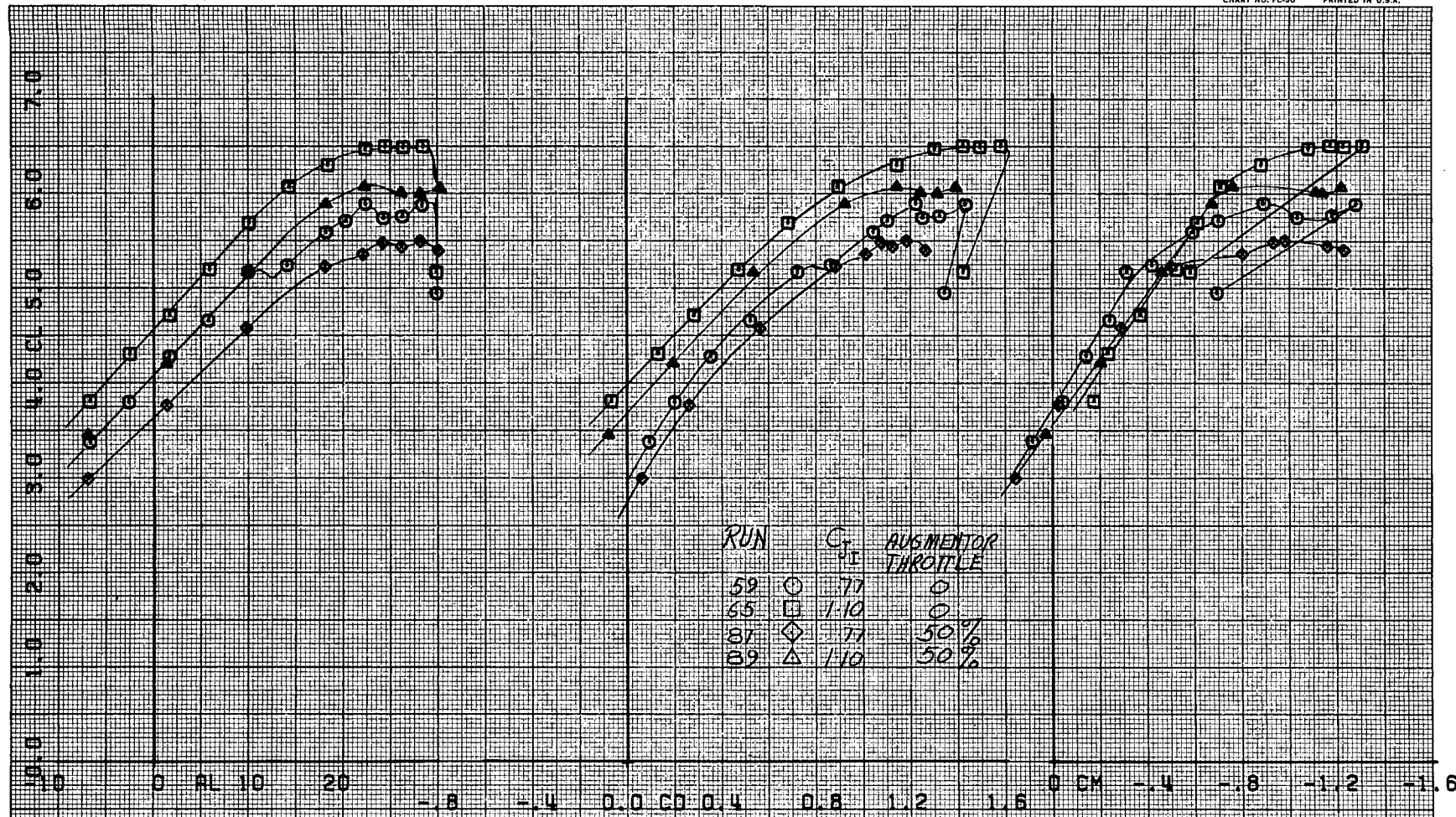
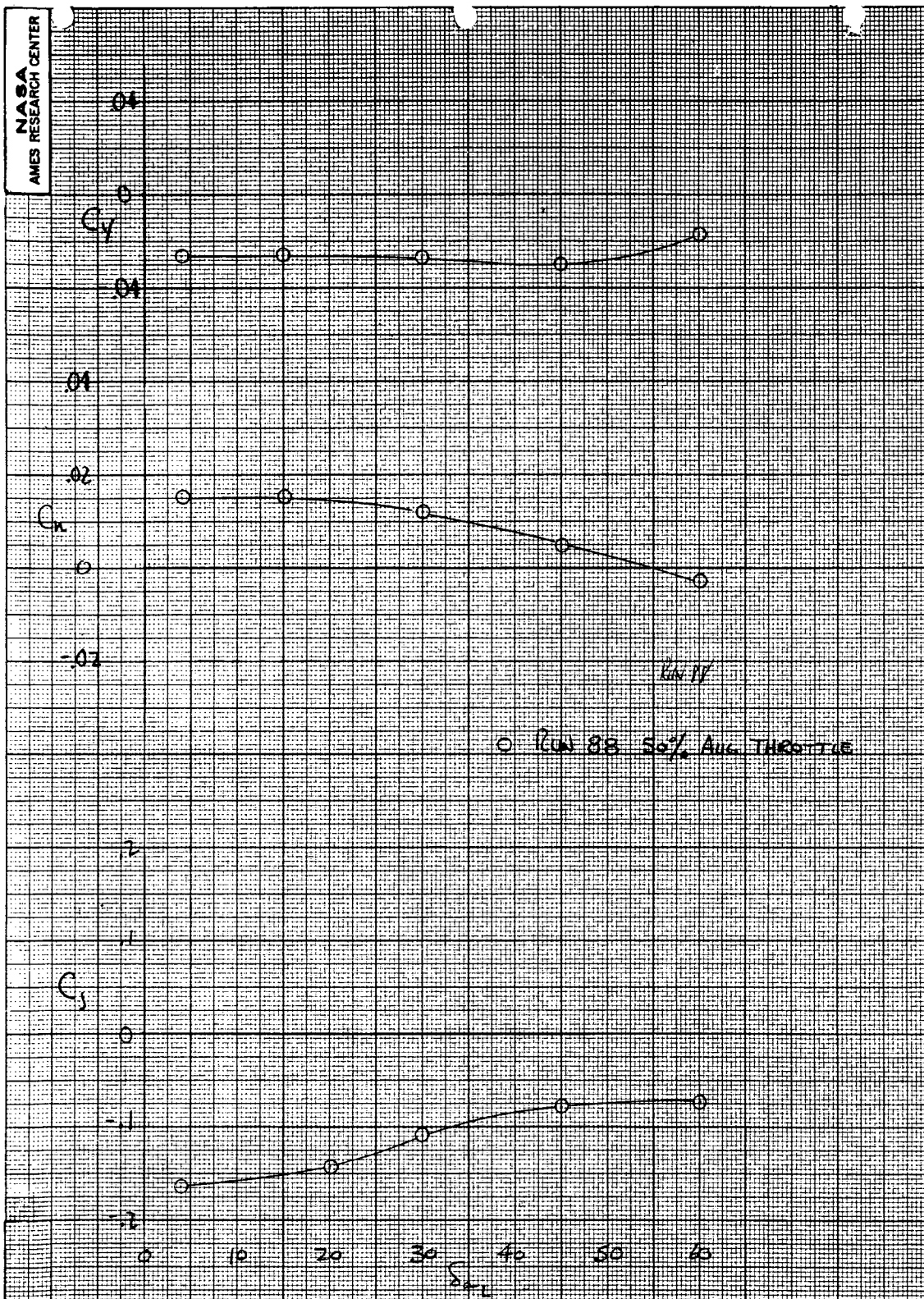
HOUSTON INSTRUMENT
DIVISION OF MARSHALL COMPANY
BELLAIRE, TEXAS
CHART NO. FC-50 PRINTED IN U.S.A.

Figure 32.- Effect of augmentor throttling on longitudinal aerodynamic characteristics with horizontal tail installed; $\delta_f = 70.6^\circ$, $\delta_s = 60^\circ$ (mod on stb'd), $i_t = -1^\circ$ and $\Delta d = 0$ and 50%.



(a) $\delta_{\alpha} = n/30^\circ$

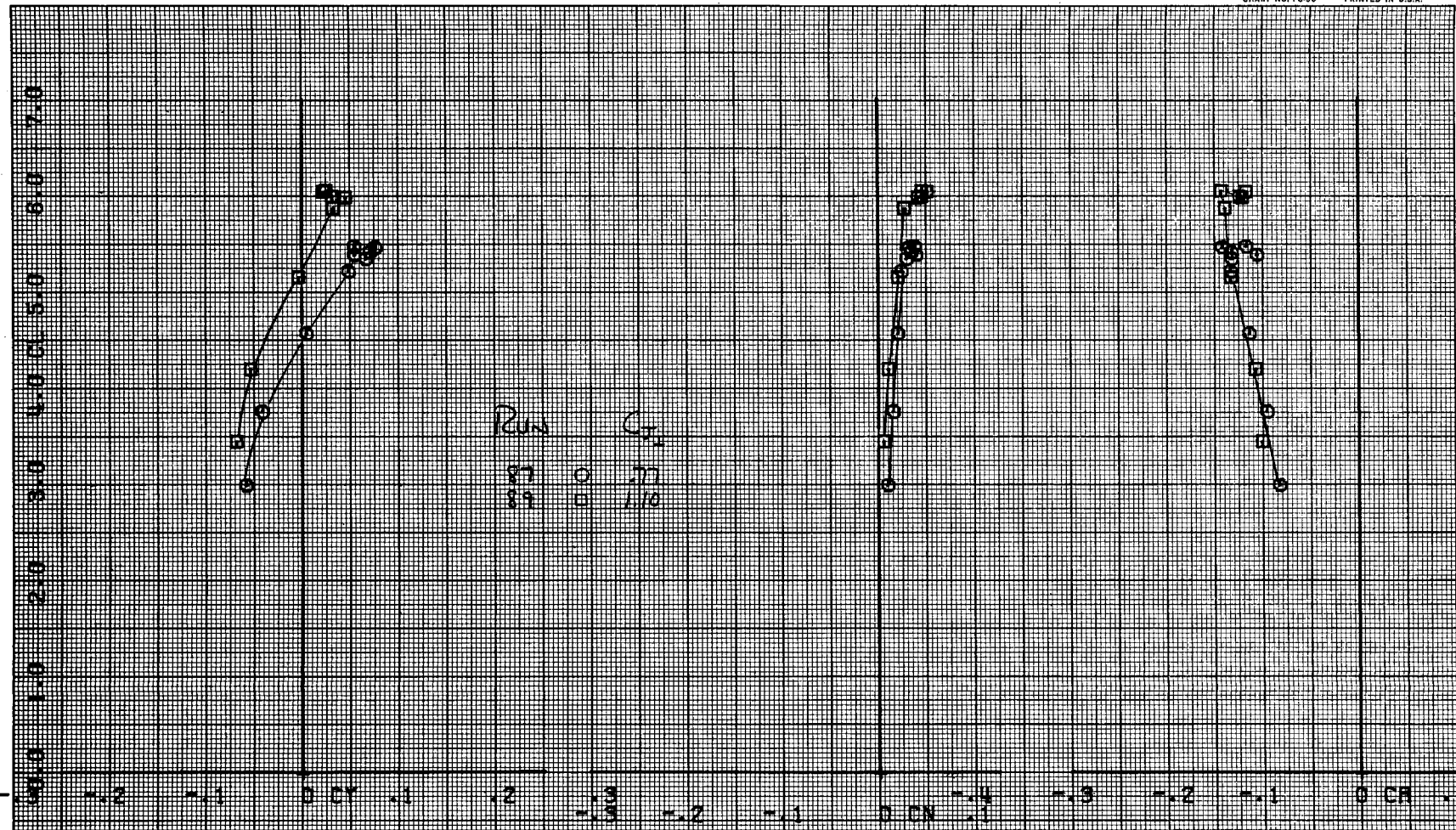
Figure 33.- Effect of augmentor throttling on lateral-directional characteristics; $\delta_f = 70.6$, $\Delta d = 50\%$.

FIRST RUN IS 87.

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(b) $C_{J_I} = .77$ and 1.10

Figure 33.- Concluded.

FIRST RUN IS 90.

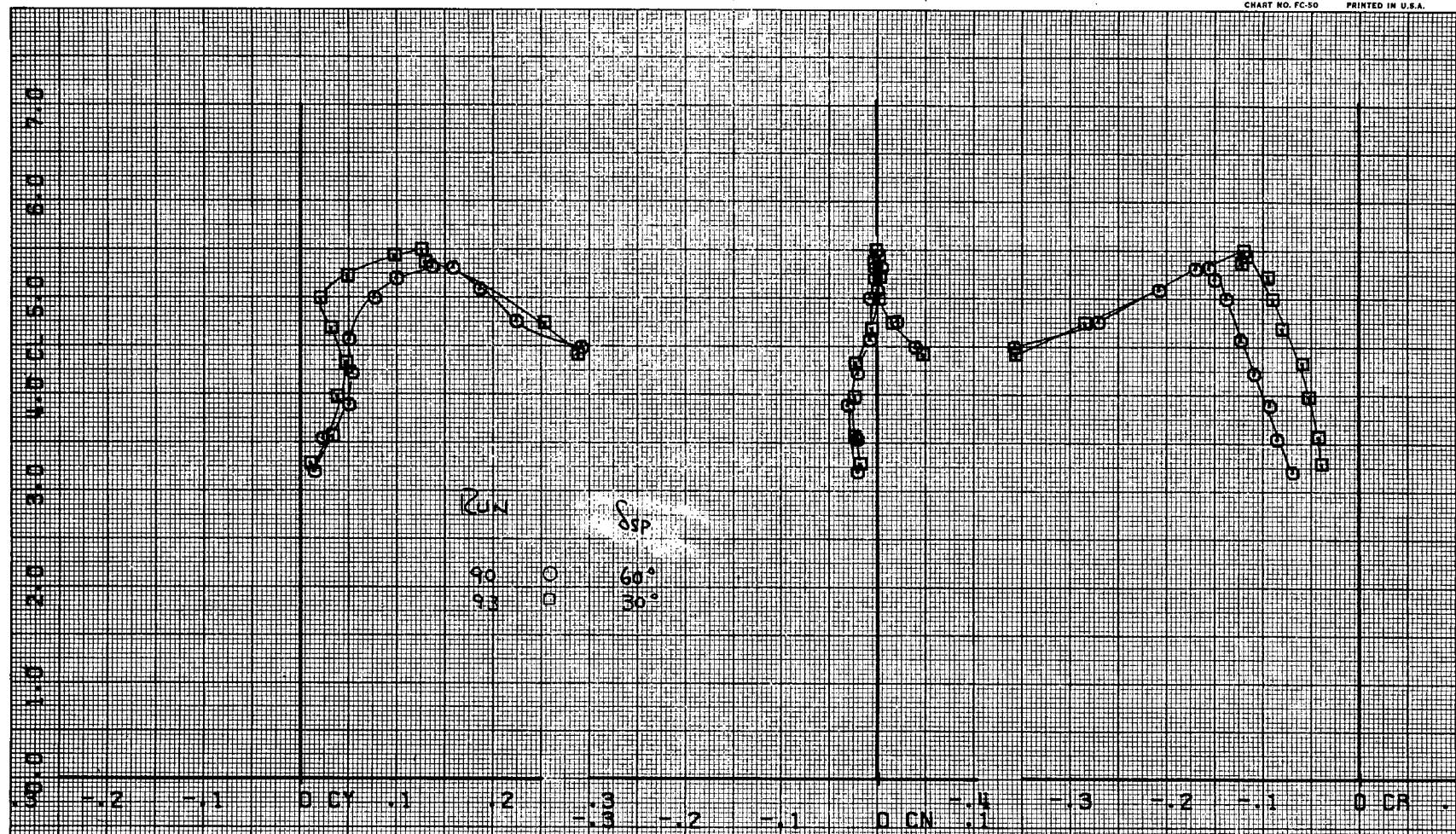
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(a) $\delta_{sp} = 30$ and 60°

Figure 34.- Effect of spoilers on lateral-directional characteristics;

$\delta_f = 70.6^\circ$.

FIRST RUN IS 90.

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OMNIGRAPHIC™

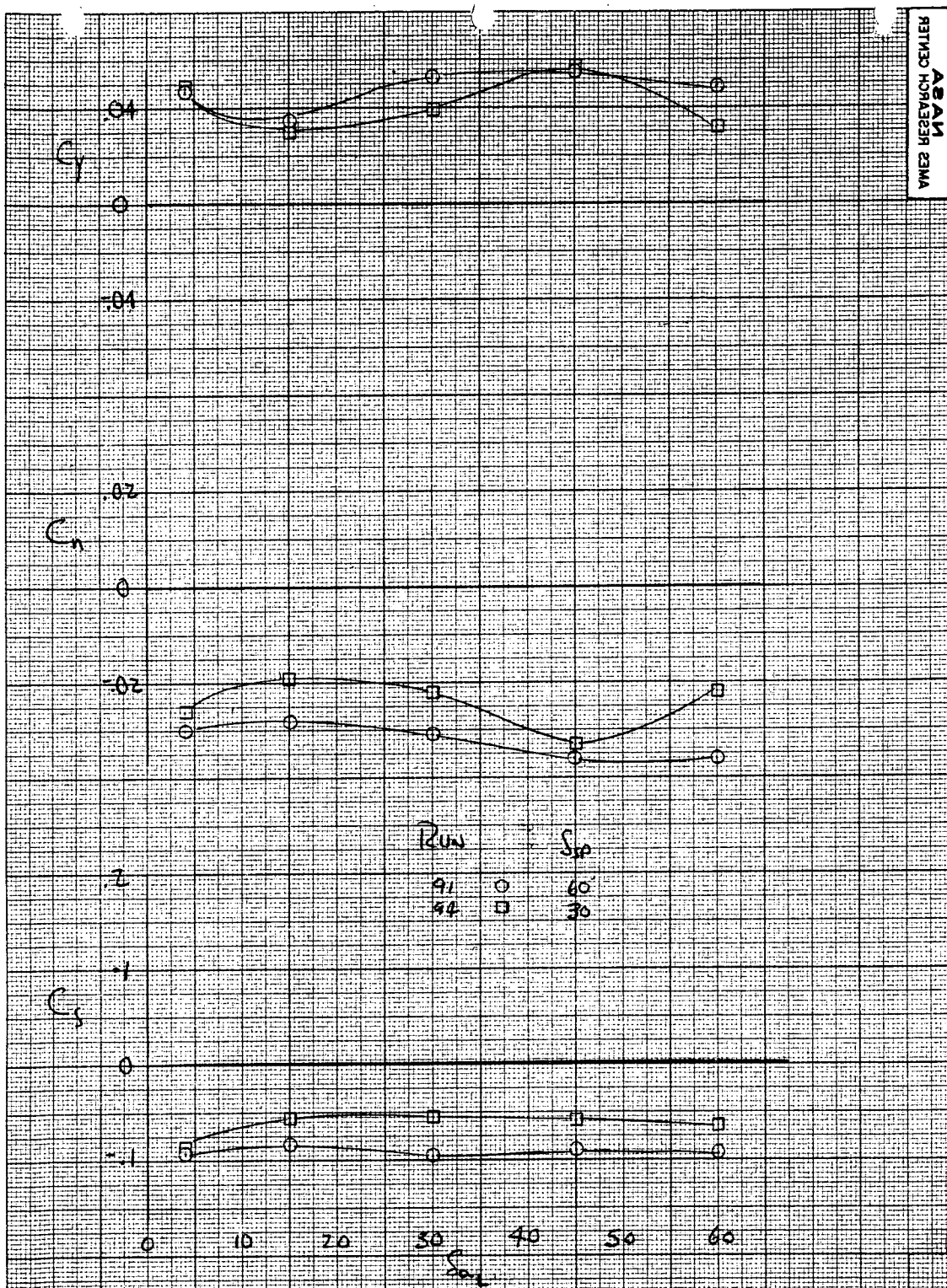
HOUSTON INSTRUMENT
DIVISION OF BARNETT-CLOUD®
BELL LAIR, TEXAS
CHART NO. FC-50 PRINTED IN U.S.A.

68



(b) $\delta_{sp} = 60^\circ$ and $C_{J_I} = .77$ and 1.10

Figure 34.- Continued.



(c) $\delta_{sp} = 30$ and 60° and $\delta_a = n/30^\circ$
Figure 34.- Concluded.

FIRST RUN IS 90.

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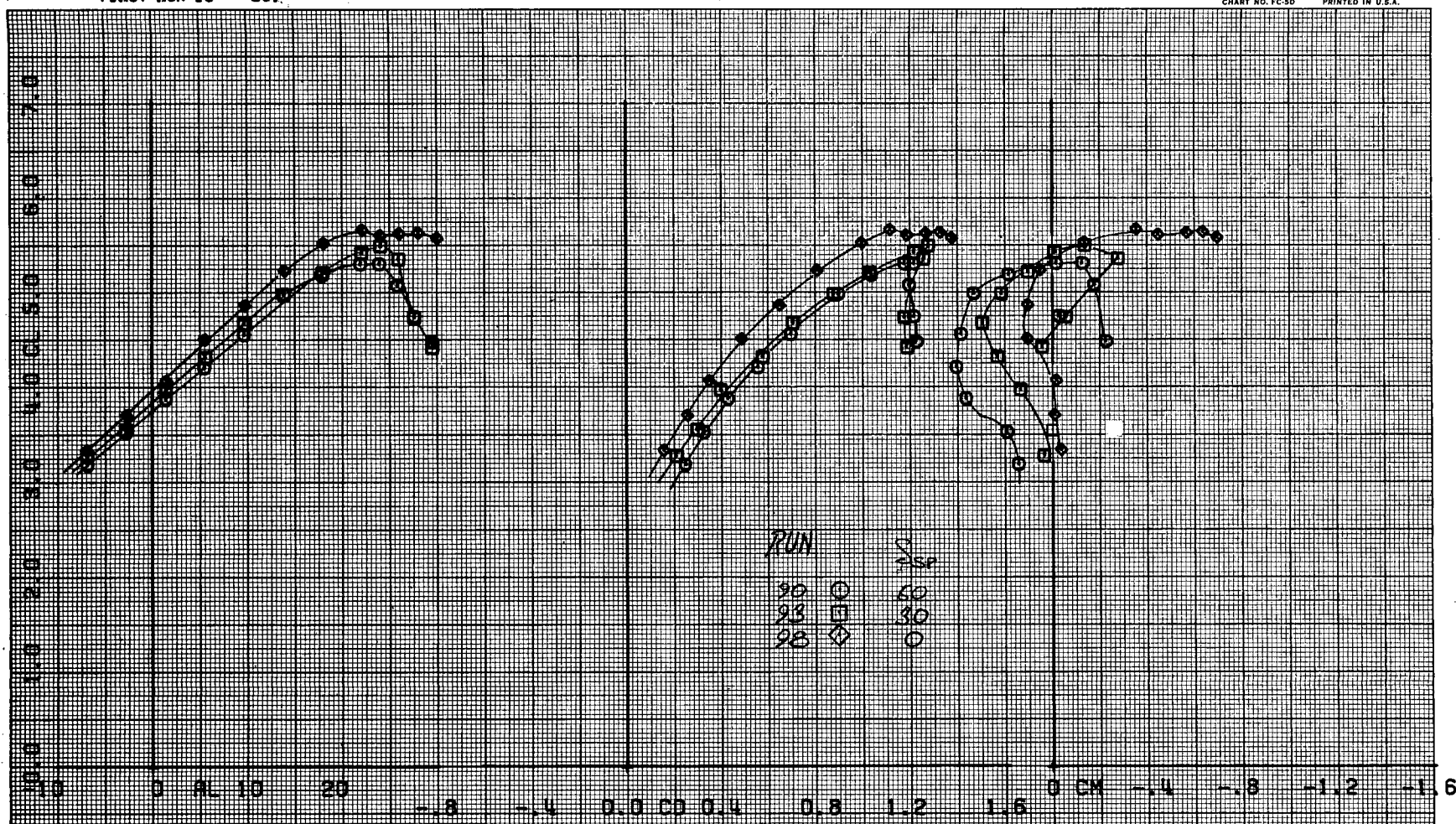
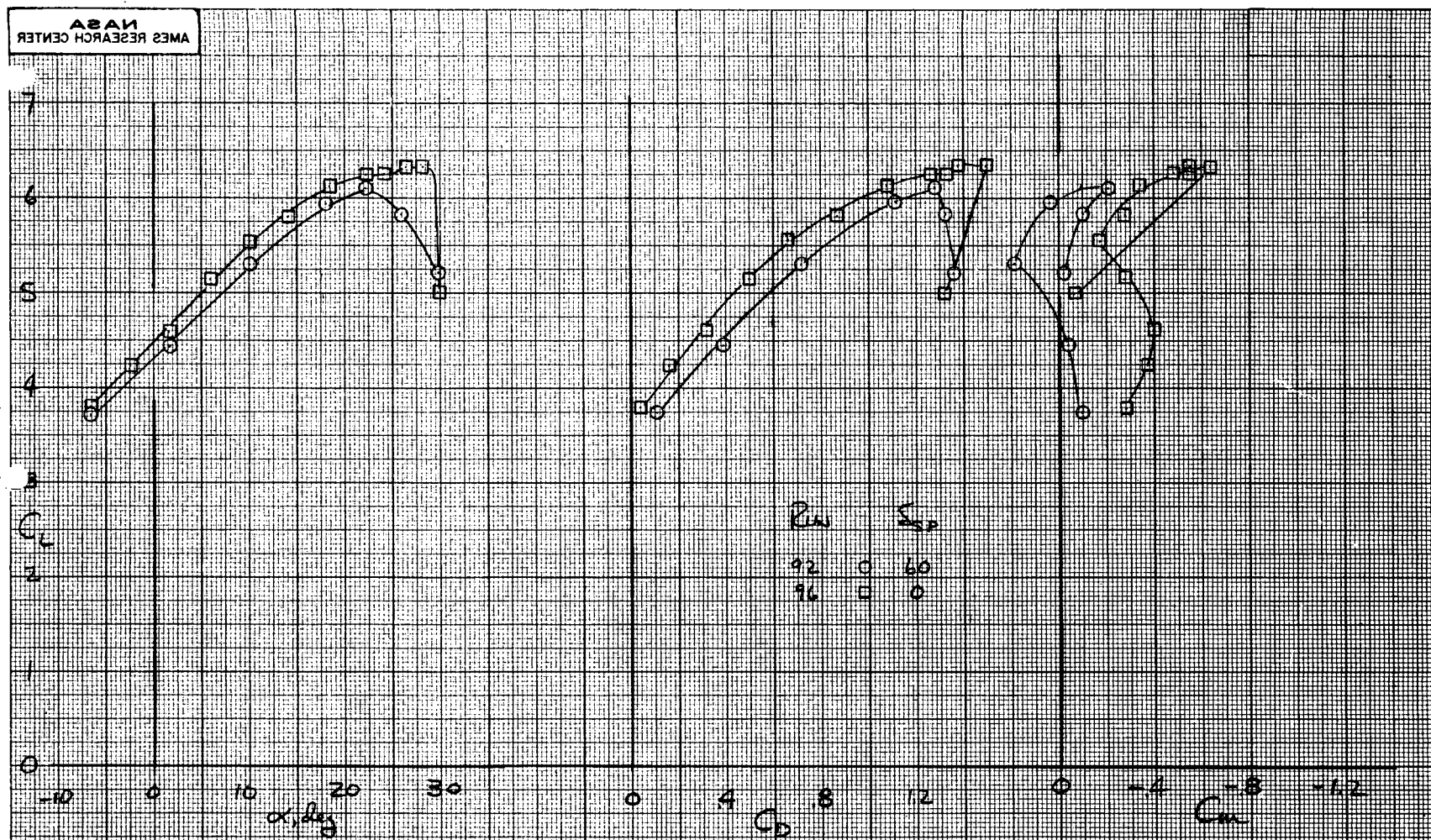
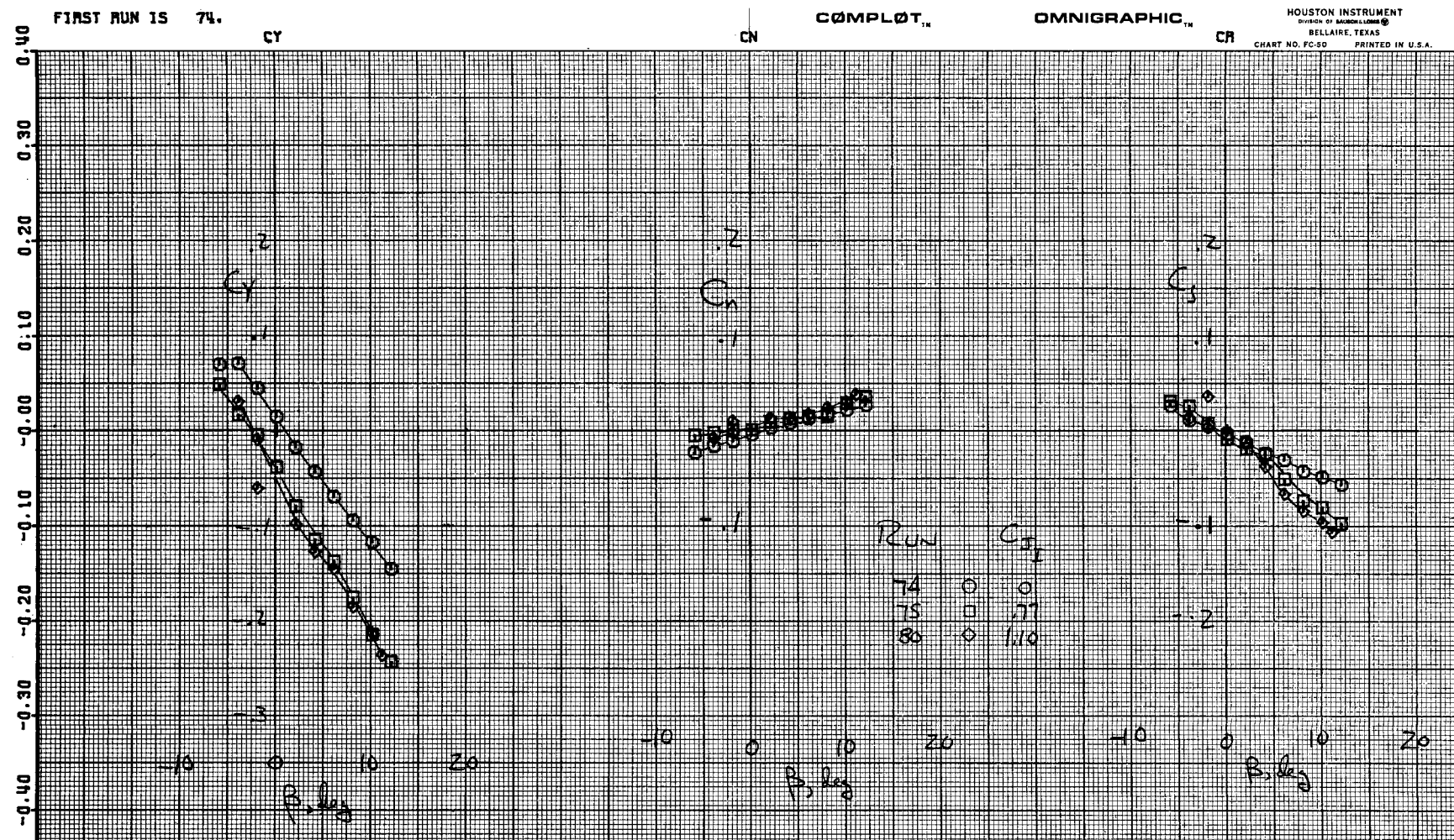
HOUSTON INSTRUMENT
DIVISION OF BELL & HOWELL
BELLARE, TEXAS
CHART NO. FC-50 PRINTED IN U.S.A.(a) $C_{J_I} = .77$

Figure 35.- Effect of spoilers on longitudinal aerodynamic characteristics with horizontal tail installed;
 $\delta_f = 70.6^\circ$, $\delta_s = 60^\circ$ (mod to stb'd), $i_t = -10.1^\circ$.



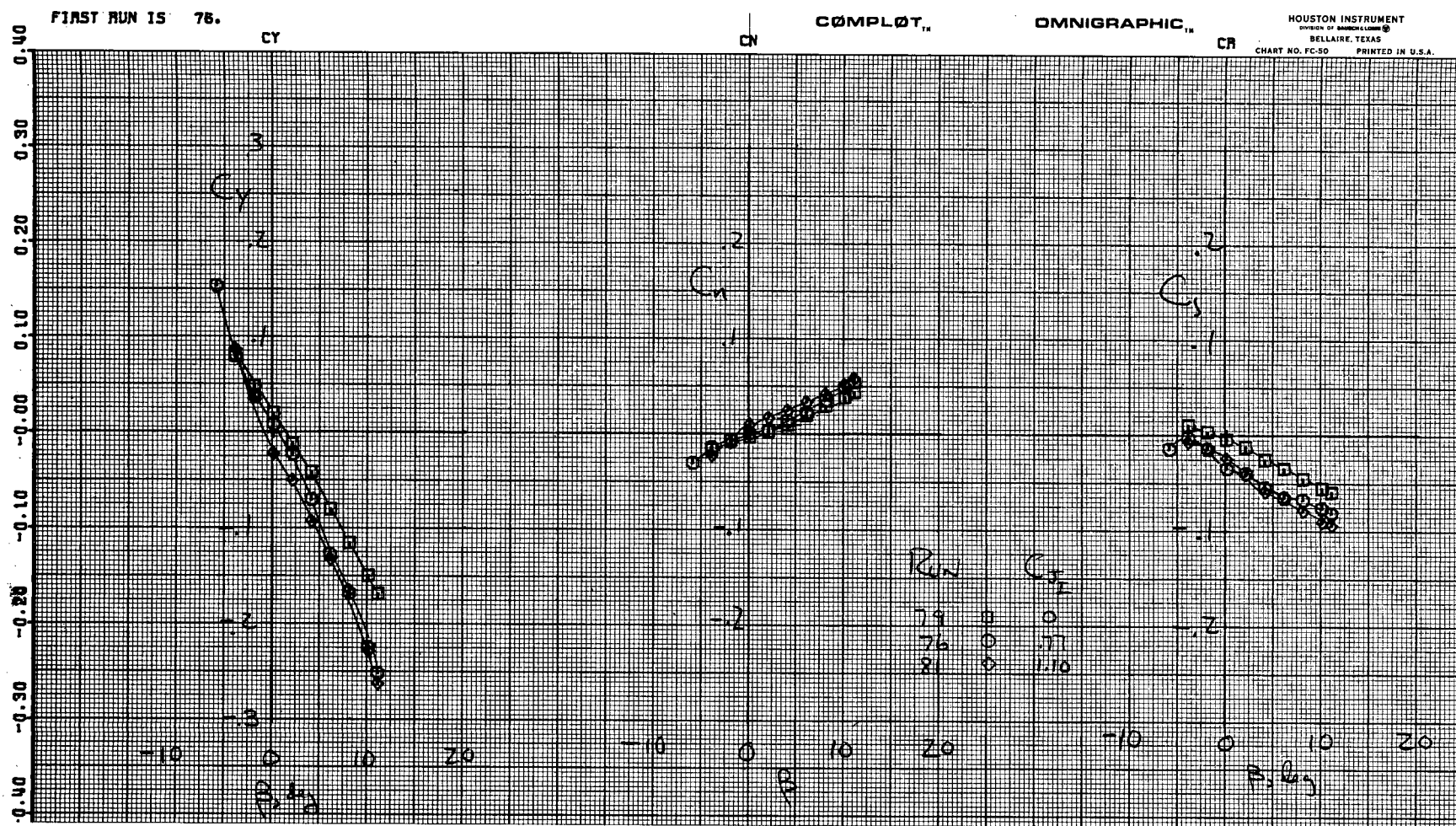
(b) $C_{J_I} = 1.10$

Figure 35.- Concluded.



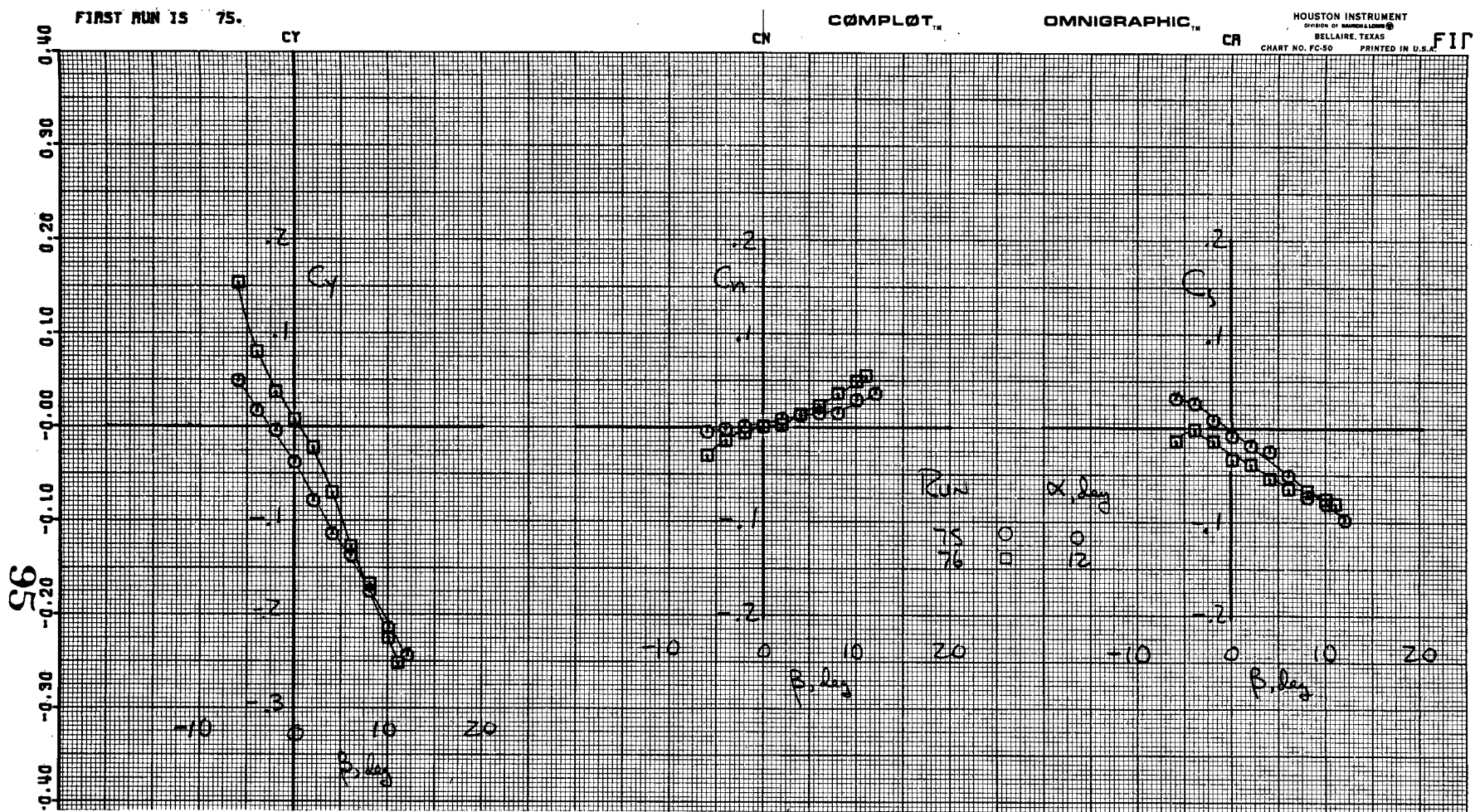
(a) Effect of C_{J_I} ; $\alpha = 0^\circ$

Figure 36.- Lateral-directional characteristics;
 $\delta_f = 70.6^\circ$.



(b) Effect of C_{JI} ; $\alpha = 12^\circ$

Figure 36.- Continued.



(c) Effect of α ; $C_{JI} = .77$
Figure 36.- Continued.

FIRST RUN IS 75.

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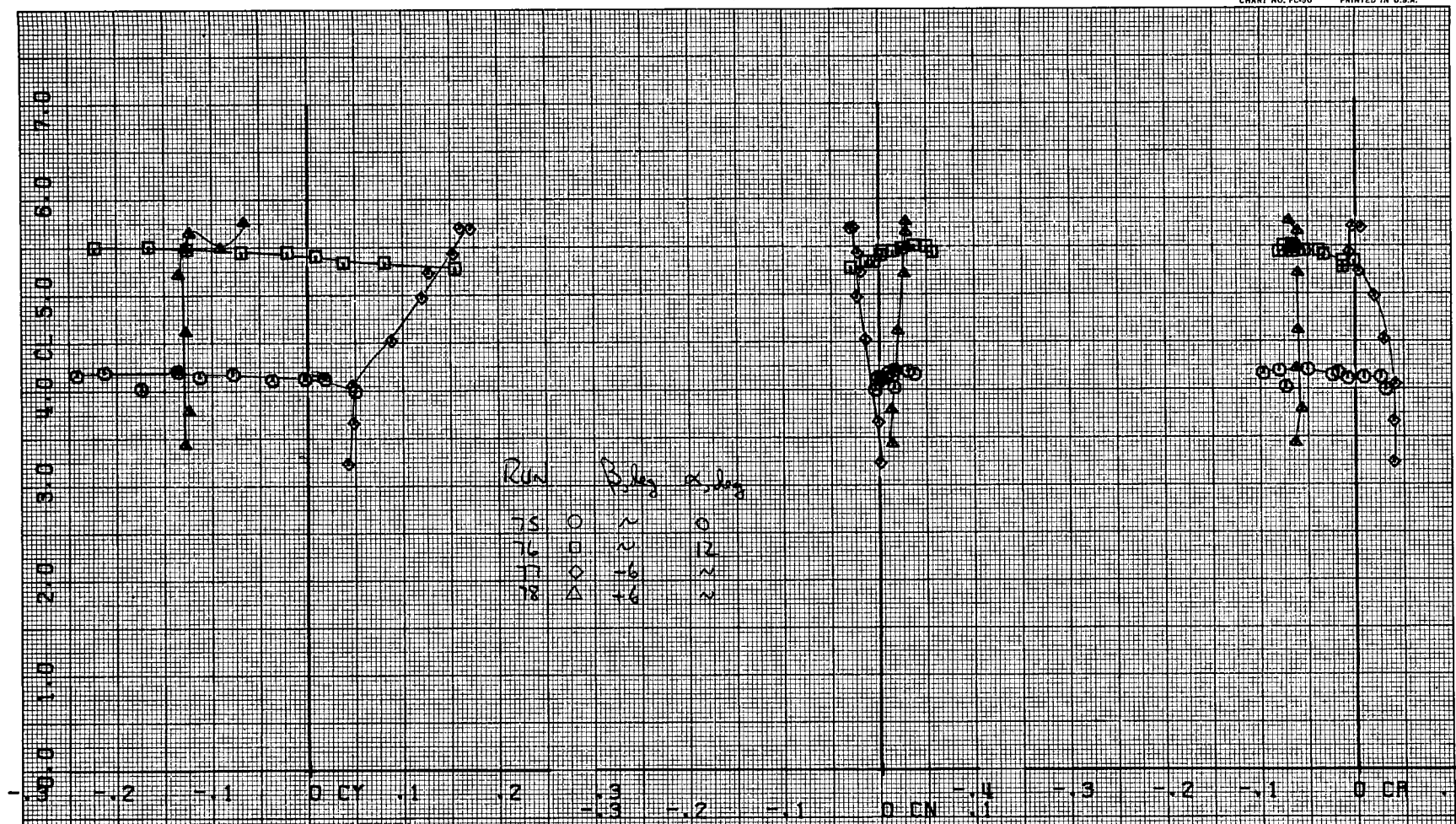
HOUSTON INSTRUMENT
DIVISION OF MATHCO, INC.
BELLAIRE, TEXAS
CHART NO. FC-50 PRINTED IN U.S.A.(d) Effect of α and β ; $C_{J_I} = .77$

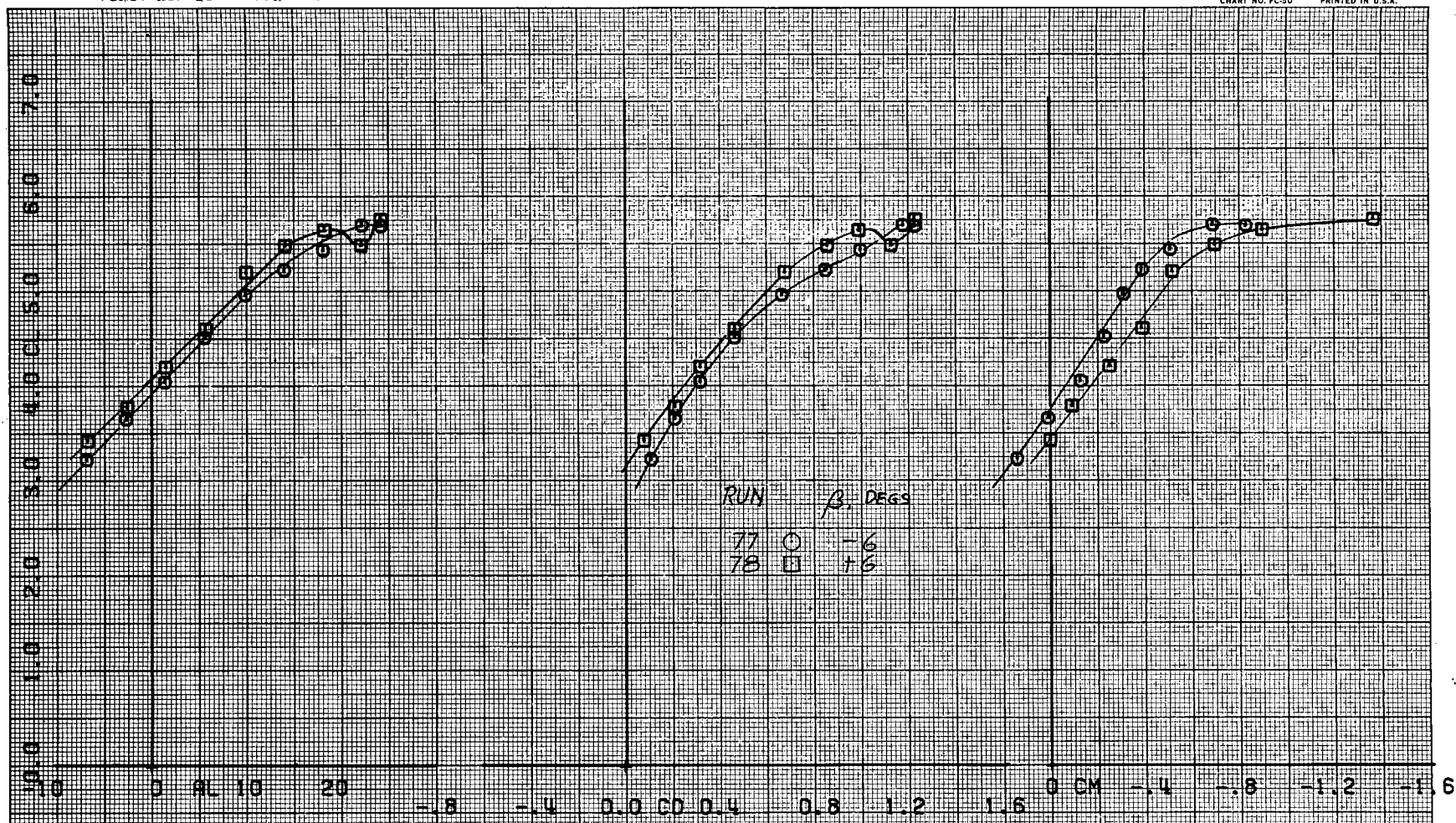
Figure 36.- Continued.

FIRST RUN IS 77.

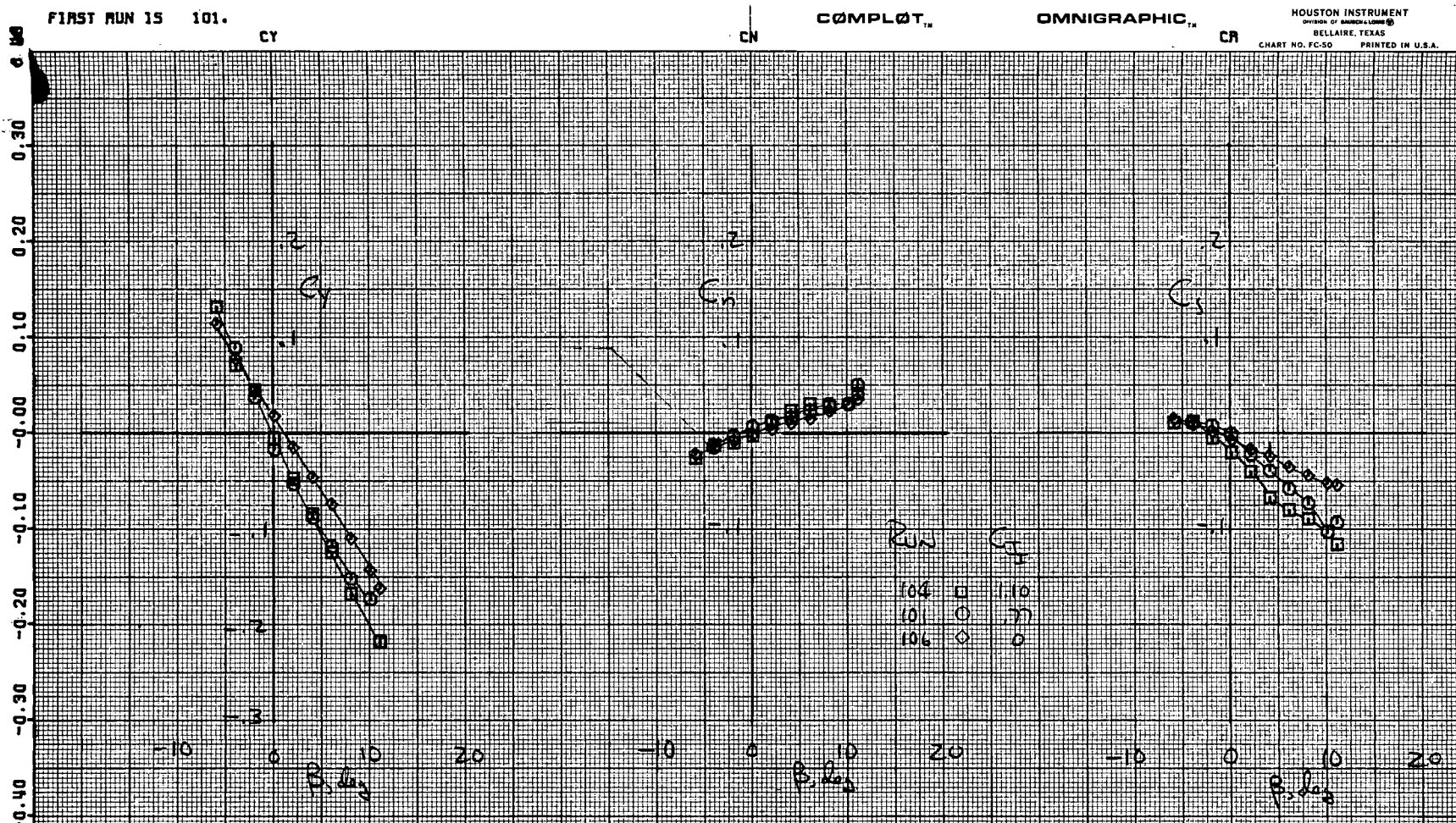
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DIVISION OF BRANCH ENGINEERING
BELL LAIR, TEXAS
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(e) Effect of β on longitudinal characteristics
Figure 34.- Concluded.



(a) Effect of C_{J_I} ; $\alpha = 4^\circ$

Figure 37.- Lateral-directional characteristics; $\delta_f = 41.1$.

FIRST RUN 15 102.

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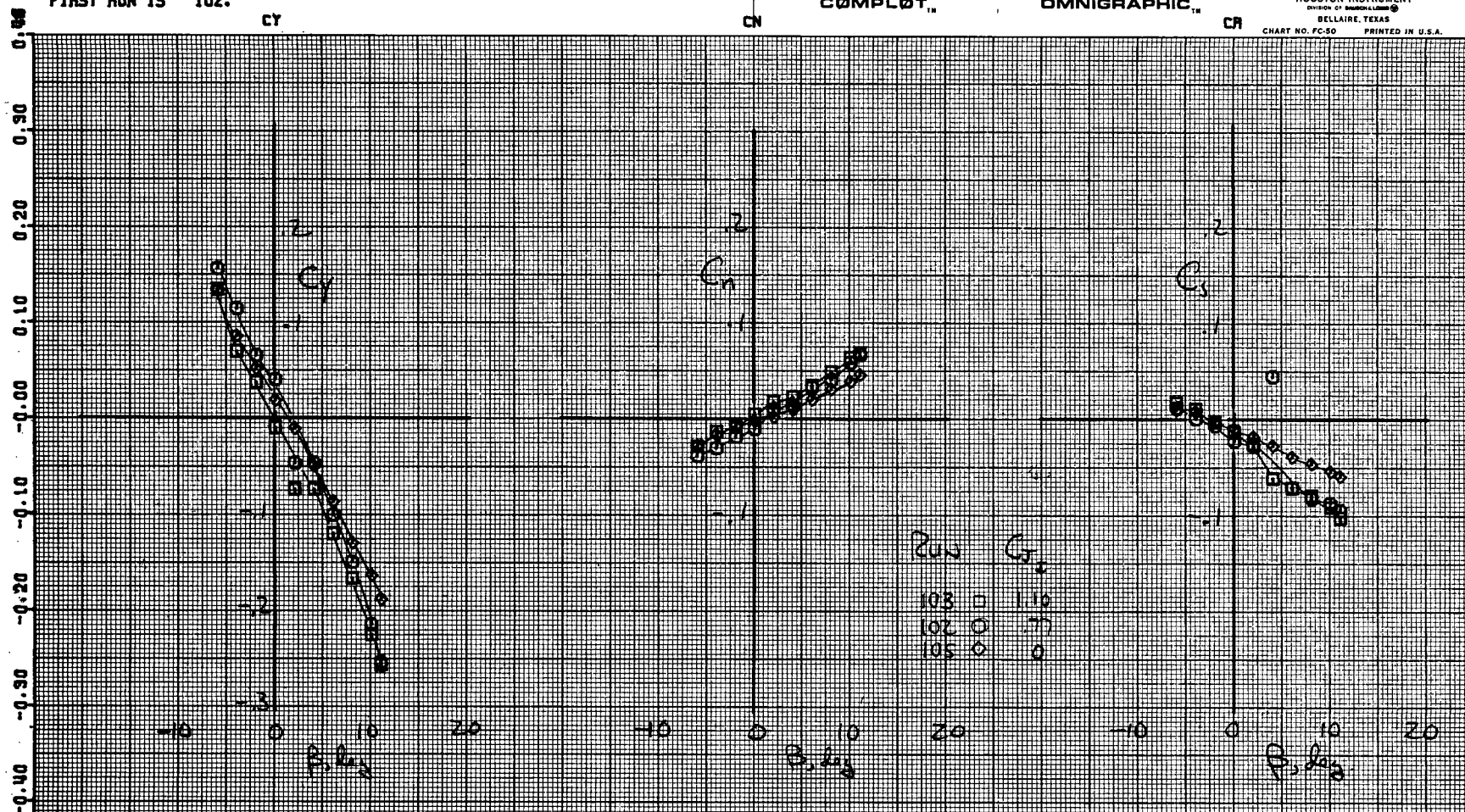
(b) Effect of C_{JI} ; $\alpha = 12^\circ$

Figure 37.- Continued.

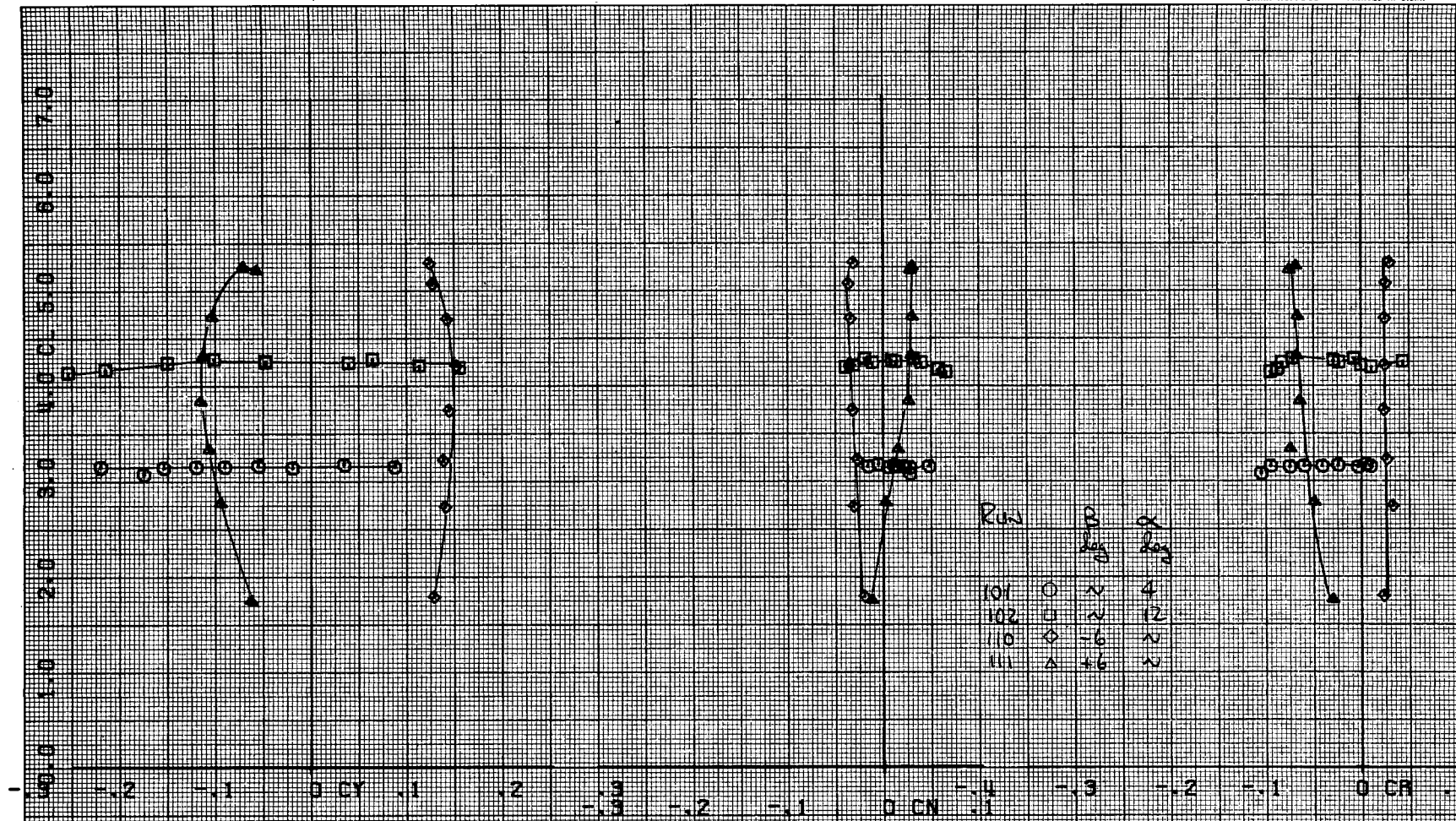
FIRST RUN IS 101.

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100



(c) Effect of α and β
Figure 37.- Concluded.

FIRST RUN IS 110.

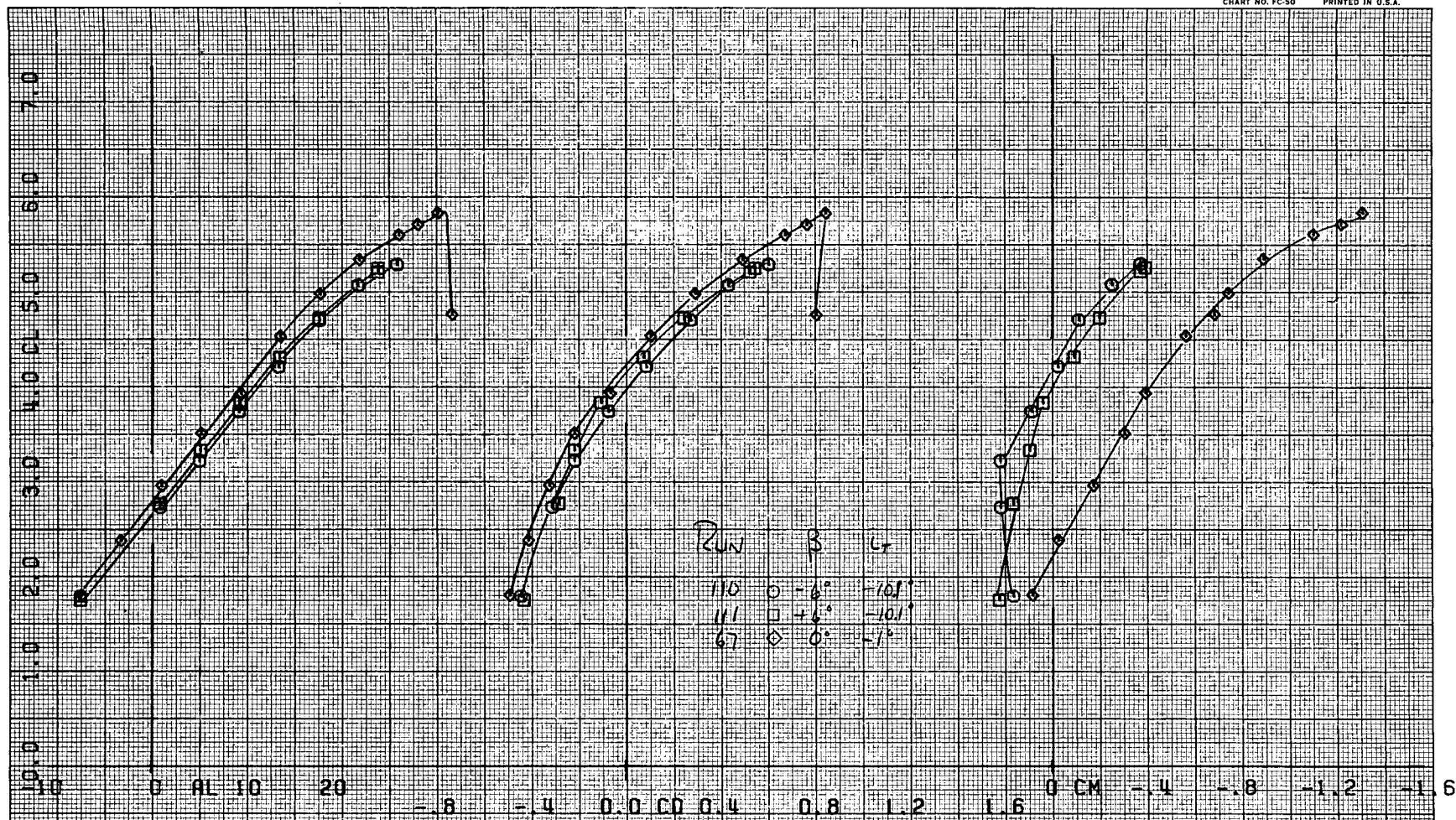
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DIVISION OF BAUGHN & COMPANY
BELLAIRE, TEXAS
CHART NO. FC-50 PRINTED IN U.S.A.

Figure 38.- Effect of sideslip on longitudinal aerodynamic characteristics with horizontal tail installed; $\delta_f = 41.1$, $\delta_s = 60^\circ$ (mod to stb'd).

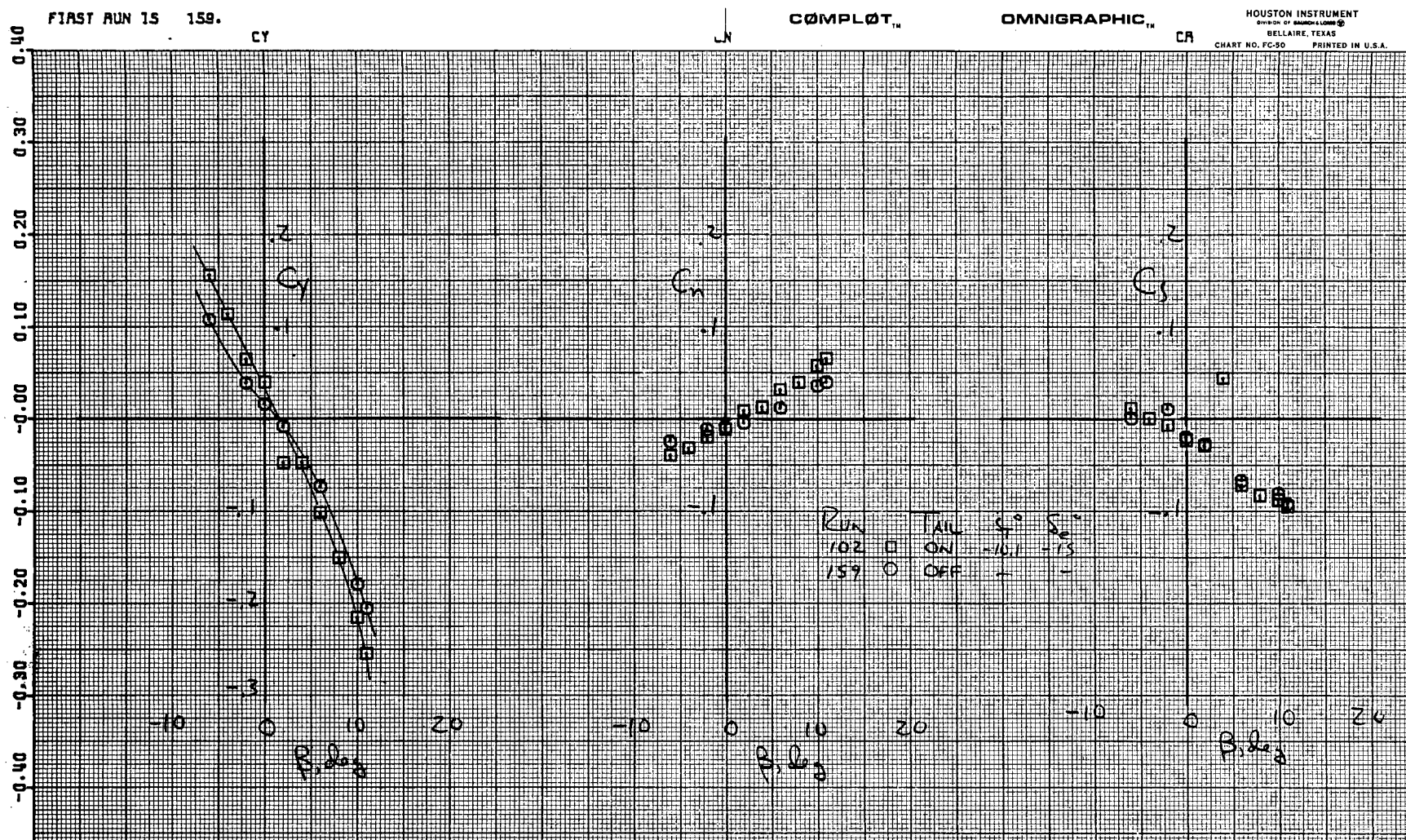


Figure 39.- Effect of horizontal tail on lateral-directional characteristics; $\delta_f = 41.1^\circ$.